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Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

# CANADIAN SILICA RESOURCES: A STUDY OF THE PROCESSING OF SELECTED SILICA SAMPLES FROM NOVA SCOTIA, NEW BRUNSWICK, MANITOBA, SASKATCHEWAN AND BRITISH COLUMBIA FOR GLASS AND FOUNDRY SAND

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by

R.K. Collings* and P.R.A. Andrews**

## SUMMARY

In cooperation with the Departments of Mines and Energy for Nova Scotia and Manitoba and various silica producers in New Brunswick, Saskatchewan and British Columbia, samples of silica sand were provided for evaluation as glass and foundry sand by CANMET. Head sample analyses ranged from 69.70 to 98.80% $SiO_2$; 0.06 to 3.24% $Fe_2O_3$ and 0.17 to 13.20% $Al_2O_3$. Impurities included pyrite, goethite, iron oxides, ilmenite, rutile, garnet, chlorite, sphene, mica, kyanite, zircon, amphibole, calcite and alumino-silicates as clay and feldspar.

Since the samples were all less than 1 mm in size, further size reduction was not necessary. The +600 µm fraction was removed by screening and removal of fines was achieved by attrition scrubbing and washing. Further removal of impurities was achieved by reverse flotation of iron oxide and alumino-silicate minerals employing both anionic and cationic collectors. Flotation resulted in a substantial improvement in the quality of most samples, the quartz concentrates analysing 79.00 to 99.53% $SiO_2$, 0.03 to 0.17% $Fe_2O_3$ and 0.07 to 11.60% $Al_2O_3$. Removal of iron oxide minerals was investigated using both wet and dry high intensity magnetic separation. Iron oxide analyses of the non-magnetic fractions were similar to the iron oxide analyses of the quartz flotation concentrates.

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On the basis of the samples submitted, silica from five of the seven deposits studied has potential as source material for glass sand. Foundry evaluation tests of seven submitted samples demonstrated some potential as moulding sand; however, tests were not conclusive.

# RESSOURCES CANADIENNES EN SILICE: ÉTUDE DU TRAITEMENT D'ÉCHANTILLONS DE SILICE SÉLECTIONNÉS PROVENANT DE LA NOUVELLE-ÉCOSSE, DU NOUVEAU-BRUNSWICK, DU MANITOBA, DE LA SASKATCHEWAN ET DE LA COLOMBIE-BRITANNIQUE EN TANT QUE SABLE DE FONDERIE ET DE SABLE CONVENANT À LA FABRICATION DU VERRE.

par

R.K. Collings* et P.R.A. Andrews**

## RÉSUMÉ

Les ministères des Mines et de l'Énergie de la Nouvelle-Écosse et du Manitoba et divers producteurs de silice du Nouveau-Brunswick, de la Saskatchewan et de la Colombie-Britannique ont collaboré pour soumettre au CANMET des échantillons de sable quartzeux pour les faire évaluer en tant que sable de fonderie et de sable approprié à la fabrication du verre. Les analyses des échantillons de matériaux superficiels d'origine préglaciaire avaient une teneur variant de 69,70 à 98,80 % en $SiO_2$; de 0,06 à 3,24 % en $Fe2O_3$, et de 0,17 à 13,20 % en $AI_2O_3$. Les impuretés comprenaient du minerai de pyrite, de goethite, d'oxyde de fer, d'ilmenite, de rutile, de grenat, de chlorite, de sphène, de mica, de kyanite, de zircon, d'amphibole, de calcite, et des alumino-silicates tels l'argile et le feldspath.

La granulométrie de la majorité des échantillons étant moindre que 1mm, il n'a pas été nécessaire de les réduire à nouveau. On a éliminé la fraction +600 µm par criblage et le minerai fin par nettoyage par attrition et lavage. L'extraction du minerai fin s'est poursuivie par la flottation inversée du minerai d'oxide ferreux et des alumino-silicates au moyen de collecteurs anionique et cationique. La flottation a permis d'améliorer considérablement la qualité de la plupart des échantillons: les concentrés de quartz soumis à une analyse avaient une teneur en $SiO_2$ variant de 79,00 à 99,53 %, en $Fe_2O_3$, de 0,03 à 0,17 % et en $Al_2O_3$ de 0,07 à 11,60 % . L'extraction des minéraux d'oxyde de fer a été investiguée au moyen de la séparation magnétique à haute intensité par voie sèche et par voie humide. Les résultats découlant des analyses des fractions non magnétiques au moyen d'oxyde de fer étaient semblables à ceux provenant des analyses par oxyde de fer de concentrés de quartz préalablement soumis au procédé de flottation.

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En se basant sur les échantillons présentés, la silice provenant de cinq des sept gisements étudiés offre des possibilités en tant que matière première pour la fabrication de sable de verrerie. Sept échantillons qui ont été soumis à des essais en fonderie ont démontré des possibilités comme sable de moulage; cependant, les essais n'ont pas été concluants.

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# INTRODUCTION

Canada continues to import significant quantities of high-purity sand, chiefly from the United States, for use in glass manufacture and by the foundry industry. Imports in 1983, for example, were 0.98 Mt valued at $16.9 million[1].

There are a number of potential sources of high-purity silica sand in Canada. This fact and the need for further study was highlighted at the Federal-Provincial Industrial Minerals Seminar that was held in 1980 in Ottawa[2]. Discussions within CANMET following that meeting resulted in a decision to initiate a laboratory study and appraisal of the technical feasibility of producing silica sand for glass and foundry applications for domestic consumption and export, from a few of the more attractive deposits. Glass sand specifications usually stipulate that all sand should be between 600 and 100 μm in size, and have the following minimal chemical analyses, 99.6% $SiO_2$, 0.03% $Fe_2O_3$, 0.15% $Al_2O_3$, with low lime and magnesia. Iron and steel foundry sands vary in grain size between 850 and 75 μm in closely sized ranges. AFS (American Foundryman's Society) numbers vary between 55 and 65, with the bulk of the sand preferably being on three adjacent sieves. A rounded grain shape is preferred. The quartz content should be high, 99% $SiO_2$, with low aluminium, iron, sodium and potassium oxides, the last three acting as fluxing agents.

This 3-year study would be made in cooperation with the provincial governments and was to concentrate on Ontario in the first year, Quebec in the second and, in the third, on selected resources in several of the remaining provinces. The Ontario report[3] was published in 1983, and the Quebec report[4] in 1984. This report outlines work undertaken on silica samples from deposits in Nova Scotia, New Brunswick, Manitoba, Saskatchewan and British Columbia. Samples from Nova Scotia and Manitoba were supplied through the provincial Department of Mines and Energy while samples from New Brunswick, Saskatchewan and British Columbia were supplied by individuals in the private sector.

## SOURCE AND DESCRIPTION OF SAMPLES

A total of nine samples representing seven deposits from five provinces, and each weighing approximately 50 kg, were obtained. The nine samples, identified by letters A to I, are located on the map, Fig. 1, and described in Tables 1 and 2*.

## SAMPLE PREPARATION AND PROCESSING

In processing sandstone to sand for glass and foundry applications it is important that the parent sandstone is reduced to its natural grain size to free impurities for subsequent removal and, as well, that this be done without excessive fracturing of grains and resulting production of unwanted fines. Whole, unfractured grains are preferred in foundry moulding, and fines are detrimental in both foundry and glass applications.

Since all the samples with the exception of sample C were less than 2 mm in size, it was not necessary to stage crush by jaw, cone and roll crusher, as had been found necessary in previous studies[3,4]. After a head sample had been prepared from each for chemical and size analysis, the +600 µm oversize material was removed by screening prior to attrition scrubbing.

### ATTRITION SCRUBBING

Previous CANMET studies of the processing of sandstone-derived sand demonstrated attrition scrubbing to be an ideal secondary processing step. The intensive scrubbing aids breakdown of clay bonded compound grains and the removal of coatings and surface staining on the individual quartz particles.

Each -600 µm screened product was scrubbed in a laboratory, Wemco attrition machine at 80% solids for 20 min. The scrubbed product was then

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*An additional six samples from Nova Scotia are also shown in Fig. 1. These samples, identified as A-A to A-F were provided as part of a silica study under the Nova Scotia Mineral Development Agreement and are described separately in Appendix A.

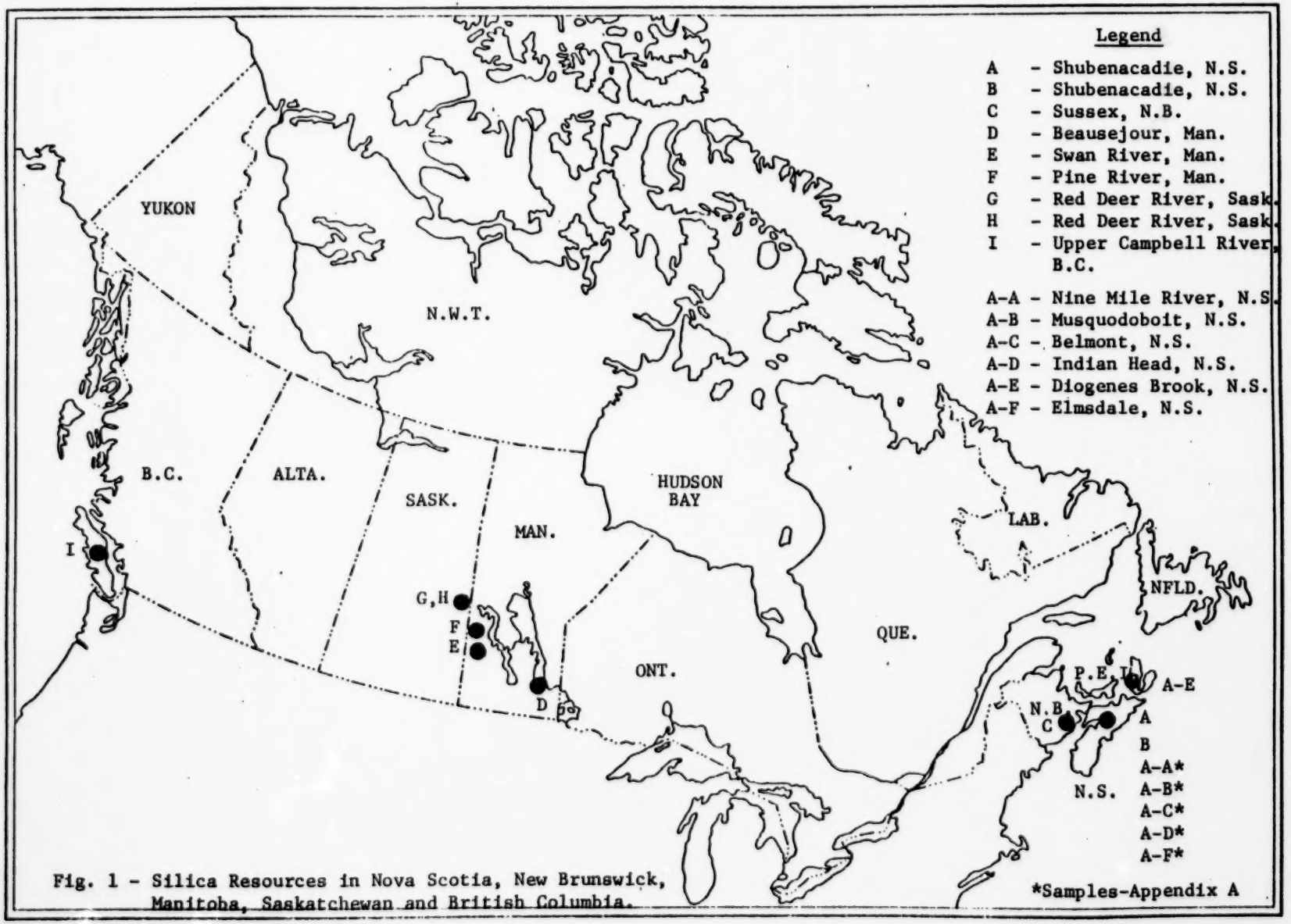


Fig. 1 - Silica Resources in Nova Scotia, New Brunswick, Manitoba, Saskatchewan and British Columbia.

washed and the sand allowed to settle. The slimes were decanted at 100 µm and the entire procedure repeated. Three washing-settling-decanting cycles were required to free and remove the slimes.

After removal of the slimes, each sample was dried and divided into two portions. A 15 to 20 kg portion was reserved for foundry evaluation while the remaining portion was further riffled into 1 kg lots for subsequent flotation evaluation. A head sample was reserved for mineralogical examination and sieve analysis. Sieve analysis of both the original head material and the washed attrition products are reported in Tables 3 and 4 and the results of a mineralogical examination of the washed attrition products in Table 5.

## FLOTATION

Removal of small quantities of liberated impurities by flotation is an efficient method of beneficiation. Because silica is the major constituent it is logical to float the impurities by reverse flotation leaving a pure quartz concentrate.

The procedure adopted for removal of impurities was based on the known response of the minerals to flotation. In general, flotation practice is to first float iron oxide minerals using a petroleum sulphonate collector followed by cationic flotation using amines to float alumino-silicate minerals. In the previous studies[3,4] the collector Duomeen TDO[5] (n-tallow-1,3-diaminopropane dioleate) was used successfully to float alumino-silicate minerals.

The following general procedure was therefore adopted:

Stage 1. Iron oxide flotation using Aerofloat 840[6] (natural petroleum sulphonate) at pH 3.5-4.0, employing high pulp density (=50% solids) conditioning.

Stage 2. Alumino-silicate flotation using Duomeen TDO at pH 2.0-2.2, employing high pulp density (=50% solids) conditioning.

In each stage, high pulp density conditioning was conducted for 5 min with Dowfroth 250 being added as required. Immediately following conditioning, the pulp density in each stage was reduced to 30% solids and

flotation conducted until completion, which was generally 5 min. At the end of stage 1 the quartz concentrate was filtered and washed twice to remove any residual petroleum sulphonate before repulping and proceeding to stage 2. In some tests, stage 1 was omitted as the petroleum sulphonate collector caused an excessive amount of quartz to be floated, (see Table 7). When this situation occurred, the magnetic material was first removed using an Exolon high intensity dry magnetic separator before proceeding to flotation of alumino-silicates.

At the completion of stage 2, all products were filtered, dried and selected products prepared for chemical analysis.

Complete chemical analysis of pre-flotation products, and flotation concentrates with % distributions of $SiO_2$, $Al_2O_3$ and $Fe_2O_3$, are presented in Table 6. Flotation reagent consumption values are shown in Table 7 and product balances of the best tests in Tables 8 and 9.

## MAGNETIC SEPARATION

Both wet and dry magnetic separation was conducted on each of the nine samples. Wet separation was conducted with 100 g portions of flotation feed in a Sala high gradient magnetic separator (HGMS). The current rating was set for maximum separation of iron oxide minerals and the products from each test were analysed for $Fe_2O_3$. The results, presented in Table 10, show the relative distribution of iron oxide in both the magnetic and non-magnetic fractions. The actual distributions of the non-magnetic products are presented in Table 6 for comparison with flotation recovery performance.

Dry separation was conducted using 2 kg portions of flotation feed using an Exolon high intensity magnetic separator. The current rating was set at 21A for maximum separation of magnetic material and the products from each test were analysed for $Fe_2O_3$. The results, reported in Tables 6 and 11 are similarly presented as the wet magnetic separation results.

## ELECTROSTATIC SEPARATION

Two samples, samples D and I contained high quantities of feldspar. An alternative method of separating feldspar from quartz is electrostatic separation. A 1 kg charge of washed attrition product of Sample D and Sample I were passed over a laboratory Carpco electrostatic separator. Results are reported in Table 12.

## CHEMICAL ANALYSIS

Screening, scrubbing, flotation, magnetic and electrostatic separation involve the production of a large number of products. Some required full analysis of identifiable oxides, others required only partial analysis whilst some products e.g. the fines (-100 μm) were not analysed since only a weight was required.

Flotation involves the removal of small quantities of iron oxide and alumino-silicate minerals, leaving a clean quartz concentrate; only the quartz concentrate need be analysed. Iron oxide and alumino-silicate concentrates from the best test performed on each of the nine samples were, however, analysed for $Fe_2O_3$ and $Al_2O_3$ to provide additional information.

The screened sand and attrition scrubbed sand products, flotation feed, flotation and non-magnetic quartz concentrates were analysed for:

$SiO_2$, $Fe_2O_3$, $TiO_2$, $Al_2O_3$, CaO, MgO, $Na_2O$, $K_2O$, LOI

The iron oxide and alumino-silicate concentrates from the best tests were analysed for $Fe_2O_3$ and $Al_2O_3$ and magnetic separation products for $Fe_2O_3$.

The analytical methods employed were wet chemical for $Na_2O$, $K_2O$ and LOI, and spectrographic for $SiO_2$, $Fe_2O_3$, $Al_2O_3$, $TiO_2$, CaO and MgO.

## FOUNDRY SAND EVALUATION

Approximately 15 to 20 kg of attrition scrubbed sand representing samples B, C, D, E, G and H were submitted for foundry evaluation. The evaluation was limited to the preparation of sand/clay/water mixtures and the determination of selected moulding properties of the prepared mixes.

The mixes were prepared in a small, 457 mm diameter laboratory muller. The quantities of the additives, reported in Table 13, being based on the amount of sand. Moisture was determined on the prepared moulding mix and is thus the true weight percentage of the total.

Table 13 also lists the moulding properties of the "green" sand/clay/water mixes together with typical results obtained with Ottawa silica sand. The values given for each sample are the arithmetical average of three consecutive tests.

Sample A was not submitted for evaluation since it was similar to B. Sample F was not submitted because there was insufficient material, nor sample I because it was too impure.

## RESULTS AND EVALUATION

### SCRUBBING

Since preliminary size reduction and mulling were not necessary, the grain shape of each sample remained essentially intact. The extent to which scrubbing aided breakdown of clay bonded compound grains and removed surface iron staining on quartz grains is best assessed by comparing the $Al_2O_3$ and $Fe_2O_3$ analyses before and after scrubbing. A summary of these analyses is presented in Table 14.

Samples A and B, from Shubenacadie, Nova Scotia, were relatively free of clay material. This was apparent both from observation of the unprocessed sand and of the iron oxide and alumina analyses before and after scrubbing.

Sample C from Sussex, New Brunswick, had a distinct reddish appearance; present also were sticky ball agglomerates of clay and quartz. This sample required considerable scrubbing and washing to reduce the alumina content from 6.47 to 0.55% $Al_2O_3$.

Sample D from Beausejour, Manitoba, was off white to grey in appearance indicative of a low grade quartz. Although a substantial amount of fine material was removed by scrubbing (11% by weight), the alumina analysis was relatively unchanged at 2.79% $Al_2O_3$. A possible reason for this is the presence of unliberated feldspar.

Sample E from Swan River, Manitoba, showed some iron staining in addition to slime clay. Scrubbing considerably reduced the iron oxide level to 0.08% $Fe_2O_3$ and the alumina level to 0.20% $Al_2O_3$.

Sample F from Pine River, Manitoba, contained some +600 µm clay bonded agglomerates which were easily broken up by hand and subsequently removed by scrubbing. The alumina content was reduced to 0.11% $Al_2O_3$.

Samples G and H from Red Deer River, Saskatchewan, represent the upper and lower strata of the same deposit. Each sample was low in iron oxide but high in clay content. Scrubbing reduced the alumina levels by approximately 50%.

Sample I from Upper Campbell Lake, British Columbia, was a very impure beach sand constituting ~20% iron oxides and ~30% feldspar. Scrubbing had little effect on reducing either the iron oxide or alumina levels.

With the exception of samples D and I, attrition scrubbing and washing successfully removed adhering fines, slime clay and surface iron staining from quartz grains.

## FLOTATION

In general, iron oxide and alumino-silicate minerals responded well to flotation. A comparison was made between an all flotation scheme, floating both iron oxides and alumino-silicate minerals, with a scheme employing dry magnetic separation to remove iron oxide minerals followed by flotation of alumino-silicate minerals. A summary of the analysis values of the quartz concentrates for the best test obtained with each sample using each method is presented in Table 15.

When comparing the iron oxide levels of quartz concentrates obtained by each method, generally analyses were similar in the range between 0.03% to 0.09% $Fe_2O_3$. When analyses are higher than 0.1% $Fe_2O_3$, the combined magnetic separation and flotation scheme gave better results. This suggests that at coarse sizes, 300 µm to 600 µm, magnetic separation is a more effective method than flotation for removing iron oxide minerals.

The situation for alumina is similar to that for iron oxide. Generally, analyses were similar in the range between 0.04% to 0.16% $Al_2O_3$. When analyses are higher than 3.00% $Al_2O_3$, the combined magnetic separation and flotation scheme gave better results. A possible explanation for this response is that, since magnetic separation is more effective than flotation for removing coarse iron oxide minerals and that at coarse sizes there is a greater probability of iron oxide and alumina middlings, then a portion of the alumina minerals will be removed magnetically.

## MAGNETIC SEPARATION

A summary of iron oxide removal by wet and dry magnetic separation is given in Table 16, where the iron oxide analyses of each non-magnetic product are compared.

These results indicate that either wet or dry magnetic separation would be suitable for removing iron oxide minerals.

## ELECTROSTATIC SEPARATION

Samples D and I were both unresponsive to feldspar flotation. Under certain conditions feldspar can be separated from quartz by electrostatic separation. The results reported in Table 12 indicate, however, that electrostatic separation was not successful.

## FOUNDRY SAND EVALUATION

Foundry moulding mixes made with sand samples B,C,D,E,G and H were each compared with a similarly prepared Ottawa sand-mix for mechanical properties including mouldability, permeability, green compressive, tensile, and shear strength, dry compressive strength and packing weight.

The results reported in Table 13 show that the mechanical properties of the Ottawa sand-mix standard were generally superior to those of the other sands, the difference being attributable to grain shape and texture. Some improvement undoubtedly could be effected by increasing the quantity of binder used, although an increase in binder would, in fact, increase the amount of moisture required. The moisture requirement of all sands, as tested, was somewhat less than that of the standard which, in itself, is not detrimental as lower moisture reduces casting volatiles. Similarly, lower binder requirement may also be considered beneficial because of reduced volatiles. Low volatiles are preferred as excess gases can cause defects in castings. In this regard moulds should have good permeability to permit the easy escape of gases. All samples except B and H had lower permeabilities than the Ottawa sand standard, B being within the range of the standard and H being considerably higher.

With regard to strength, only sample D compared favourably with the green compressive strength of the standard; samples, D, G and H, with the green shear strength; and samples, B, D and E, with the green tensile strength of the standard. Dry compressive strengths were all lower than the Ottawa standard. Low dry compressive strengths would contribute to the deterioration of moulds during handling.

## CONCLUSIONS

On the basis of the samples submitted, silica from five of the seven deposits included in this study (samples A,B,C,E,F,G and H) has potential as source material for glass sand. After processing, each of these samples contained less than 0.15% $Al_2O_3$, the minimum specification for glass sand. The specification for iron oxide in glass sand, 0.03% $Fe_2O_3$, was exceeded slightly for samples E and F, where levels of 0.05% $Fe_2O_3$, were obtained. These analyses could be reduced to more acceptable levels by larger scale, more efficient washing and scrubbing equipment. Samples D and I were not acceptable due to excessive levels of both iron oxide and alumina.

Despite significant deviation from the comparative Ottawa sand standard, it is probable that all the noted sands could be considered for foundry purposes. Each would require detailed evaluation, however, by potential users to ensure both suitability and acceptable costs.

## ACKNOWLEDGEMENTS

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TABLE 1. Sample identification and location

| Identification | Sample | Location |
|---|---|---|
| 85/6 | A | Shubenacadie, Nova Scotia |
| 85/7 | B | Shubenacadie, Nova Scotia |
| 84/13 | C | Sussex, New Brunswick |
| 85/1 | D | Beausejour, Manitoba |
| 85/2C | E | Swan River, Manitoba |
| 85/2P | F | Pine River, Manitoba |
| 85/10A | G | Red Deer River, Saskatchewan (upper strata) |
| 85/10B | H | Red Deer River, Saskatchewan (lower strata) |
| 85/8 | I | Upper Campbell Lake, British Columbia |

TABLE 2. Sample description

| Sample | Description |
|---|---|
| A | The sample is generally white in appearance, with sub-angular shaped quartz grains, some being opaque. Minor iron staining occurs in the finer sizes. The top size was 30 mm lumps. |
| B | The sample is generally white in appearance, with sub-angular shaped quartz grains though slightly more rounded than those in sample A. Some grains are opaque and some exhibit iron staining though less than in sample A. |
| C | The silica ranges from rounded 150 mm quartz pebbles to very fine sticky clay. The -150 +25 mm range is rounded to sub-rounded, white to translucent quartz. The -25 mm portion is characterized by a reddish appearance, indicating iron oxides; clay-bonded pink agglomerates of quartz also were present. |
| D | Only 60% of this low grade sample was composed of sub-rounded, clear grains of quartz, the remainder consisted of iron-stained quartz and clay bonded quartz agglomerates. |
| E | This sample was composed of three sections of core. The +315 µm fraction appeared to be low grade; -315 µm fraction was composed of sub-angular quartz with minor iron staining. |
| F | Approximately 10% of the sample was composed of +630 µm clay bonded quartz agglomerates. The remaining quartz was fine grained with the 200 µm grains being sub-rounded with minor clay and iron oxides. |
| G | White, fine grained sub-angular quartz with some dark iron oxides. |
| H | Buff coloured quartz, grading from coarse to fine, sub-angular in shape. Some dark iron oxides and minor iron staining on some quartz grains. |
| I | Low grade beach sand comprising ≈20% dark iron oxides, some as middlings with quartz, and ≈30% feldspar. The quartz was off white and sub-angular in grain shape. |

TABLE 3. Sieve analyses of head samples

| Size µm | Direct % Weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B* | C | D | E | F | G | H | I |
| + 630 | 8.7 | - | 66.4 | 3.0 | 0.1 | 12.5 | - | - | 1.0 |
| -630 + 400 | 15.6 | - | 10.0 | 3.5 | 0.4 | 0.2 | 0.5 | 37.1 | 11.9 |
| -400 + 315 | 13.0 | - | 3.9 | 9.4 | 1.0 | 0.2 | 4.0 | 26.0 | 15.8 |
| -315 + 200 | 30.8 | - | 5.4 | 38.2 | 18.3 | 13.8 | 57.0 | 13.5 | 37.3 |
| -200 + 160 | 14.5 | - | 7.1 | 17.6 | 21.5 | 27.0 | 18.8 | 4.2 | 16.1 |
| -160 + 100 | 15.6 | - | 2.1 | 13.9 | 39.1 | 35.3 | 11.0 | 4.0 | 16.7 |
| -100 | 1.8 | - | 10.5 | 14.4 | 19.6 | 11.0 | 8.7 | 15.2 | 1.2 |
| Total | 100.0 | - | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*Not measured, but visual inspection indicated that the head sieve analysis was similar to the washed attrition sieve analysis.

TABLE 4. Sieve analyses of washed attrition products

| Size µm | Direct % Weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C* | D | E | F | G | H | I |
| -630 + 400 | 21.8 | 21.2 | - | 3.3 | - | 1.4 | 0.5 | 42.0 | 12.6 |
| -400 + 315 | 14.8 | 20.0 | - | 8.8 | 1.0 | 1.3 | 4.3 | 29.3 | 15.6 |
| -315 + 200 | 32.2 | 29.8 | - | 41.7 | 17.4 | 17.4 | 61.8 | 15.2 | 36.2 |
| -200 + 160 | 14.0 | 12.6 | - | 20.5 | 31.3 | 31.0 | 20.3 | 4.7 | 15.4 |
| -160 + 100 | 16.0 | 15.8 | - | 22.5 | 44.8 | 39.6 | 11.9 | 4.5 | 17.8 |
| -100 | 1.2 | 0.6 | - | 3.2 | 5.5 | 9.3 | 1.2 | 4.3 | 2.4 |
| Total | 100.0 | 100.0 | - | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*Not measured since the preliminary screening was conducted at 420 µm rather than 630 µm.

TABLE 5. Mineralogical examination of washed attrition products

| Sample | |
|---|---|
| A | Quartz is the major mineral occurring as sub-angular grains; minor* minerals include ilmenite, rutile and zircon. Feldspar is present only in trace amounts. Some quartz grains show very small pyrite inclusions. |
| B | Very similar to sample A. |
| C | Quartz is present as the major mineral, occurring as sub-angular grains; minor minerals include garnet, ilmenite, goethite, rutile and mica. Some quartz grains showed minute inclusions of pyrite or rutile attached to the rim. |
| D | Quartz is present as the major mineral, occurring as sub-rounded grains; minor minerals include calcite, feldspar, sphene and mica. Some quartz grains show 5 to 10 µm size inclusions of pyrite. |
| E | Quartz is the predominant mineral, occurring as sub-angular grains; minor minerals include ilmenite, rutile, sphene. Some quartz grains show 5 to 10 µm inclusions of pyrite, zircon and apatite. |
| F | Quartz is the major mineral occurring as sub-rounded grains; minor minerals include ilmenite, rutile, barite, zircon, iron oxides and pyrite. Some quartz grains exhibit 5 to 10 µm size rutile or pyrite inclusions. |
| G | Quartz is the major mineral which occurs as sub-angular grains; minor minerals include kyanite, garnet, mica, feldspar. Some quartz with 5 to 10 µm size inclusions of ilmenite and titanite. |
| H | Quartz is the major mineral occurring as sub-angular grains; minor minerals include ilmenite, feldspar, rutile and mica. Some quartz grains have 5 to 10 µm pyrite inclusions. |
| I | Quartz and feldspar are the major minerals, the quartz occurring as sub-angular grains; minor minerals include amphibole, chlorite, garnet, ilmenite, pyrite and iron oxides. |

* Minor minerals occur as less than 10% of the sample.

TABLE 6. Chemical analyses with product distributions for $SiO_2$, $Fe_2O_3$ and $Al_2O_3$

| Products | Wt % | Analysis % | | | | | | | | | | Distribution % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | TOTAL | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| Sample A | | | | | | | | | | | | | | |
| Head sample | 100.00 | 98.76 | 0.20 | 0.37 | 0.17 | 0.02 | 0.02 | 0.03 | 0.04 | 0.20 | 99.81 | 100.0 | 100.0 | 100.0 |
| Screening | | | | | | | | | | | | | | |
| +630 µm | 11.7 | | | | | | | | | | | | | |
| -630 µm | 88.3 | 98.5 | 0.18 | 0.30 | 0.20 | 0.01 | 0.02 | 0.03 | 0.01 | 0.17 | 99.42 | 88.1 | 79.5 | 100.0 |
| Attrition Scrubbing | | | | | | | | | | | | | | |
| -630 +100 µm | 85.3 | 98.8** | 0.22 | 0.46 | 0.13 | 0.02 | 0.01 | 0.03 | 0.02 | 0.17 | 99.86 | 85.3 | 93.8 | 65.2 |
| -100 µm | 3.0 | | | | | | | | | | | | | |
| Magnetic Separation | | | | | | | | | | | | | | |
| Wet (Sala) | 74.4 | 99.0** | 0.04 | 0.02 | 0.14 | 0.01 | 0.02 | 0.01 | 0.09 | 0.22 | 99.55 | 74.6 | 14.9 | 61.3 |
| Dry (Exolon) | 82.7 | 99.0 | 0.04 | 0.02* | 0.14 | 0.02 | 0.02 | 0.01 | 0.01 | 0.15 | 99.41 | 82.9 | 16.5 | 68.1 |
| Flotation Concns | | | | | | | | | | | | | | |
| Test 32 | 31.5 | 99.45 | 0.07 | 0.09 | 0.05 | 0.01 | 0.02 | 0.01 | 0.01 | 0.14 | 99.85 | 31.7 | 11.0 | 9.3 |
| Test 33 | 59.8 | 99.60 | 0.04 | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 | 0.15 | 99.89 | 60.3 | 12.0 | 17.6 |
| Test 37 | 80.6 | 99.46 | 0.06 | 0.05 | 0.06 | 0.01 | 0.01 | 0.01 | 0.01 | 0.12 | 99.79 | 81.2 | 24.2 | 28.5 |
| Test 38 | 72.2 | 99.48 | 0.04 | 0.02 | 0.06 | 0.01 | 0.01 | 0.01 | 0.02 | 0.13 | 99.78 | 72.7 | 14.4 | 25.5 |
| Test 41 | 79.8 | 99.60 | 0.04 | 0.01 | 0.10 | 0.01 | 0.01 | 0.01 | 0.01 | 0.12 | 99.91 | 80.5 | 16.0 | 46.9 |
| Test 42 | 74.0 | 99.40 | 0.04 | 0.01 | 0.08 | 0.01 | 0.01 | 0.01 | 0.01 | 0.12 | 99.69 | 74.5 | 14.8 | 34.8 |

* Estimated
**Calculated by difference

TABLE 6. Continued

| Products | Wt % | Analysis % | | | | | | | | | | Distribution % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | TOTAL | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| Sample B | | | | | | | | | | | | | | |
| Head sample | 100.00 | 98.8* | 0.20* | 0.37* | 0.17* | 0.02* | 0.02* | 0.03* | 0.04* | 0.20* | 99.81 | 100.0 | 100.0 | 100.0 |
| Screening | | | | | | | | | | | | | | |
| +630 µm | | | | | | | | | | | | | | |
| -630 µm | 100.0 | 98.8 | 0.20 | 0.37 | 0.17 | 0.02 | 0.02 | 0.03 | 0.04 | 0.20 | 99.81 | 100.0 | 100.0 | 100.0 |
| Attrition Scrubbing | | | | | | | | | | | | | | |
| -630 +100 µm | 96.5 | 99.0** | 0.19 | 0.32 | 0.18 | 0.01 | 0.02 | 0.01 | 0.03 | 0.18 | 99.91 | 96.7 | 91.7 | 100.0 |
| -100 µm | 3.5 | | | | | | | | | | | | | |
| Magnetic Separation | | | | | | | | | | | | | | |
| Wet (Sala) | 87.3 | 99.35 | 0.04 | 0.01 | 0.18 | 0.01 | 0.01 | 0.01 | 0.02 | 0.15 | 99.78 | 87.8 | 17.5 | 92.4 |
| Dry (Exolon) | 94.9 | 99.3* | 0.04 | 0.03 | 0.09 | 0.01 | 0.02 | 0.01 | 0.01 | 0.11 | 99.62 | 95.4 | 19.0 | 50.2 |
| Flotation Concns | | | | | | | | | | | | | | |
| Test 43 | 52.8 | 98.8 | 0.04 | 0.02 | 0.06 | 0.01 | 0.01 | 0.01 | 0.02 | 0.13 | 99.10 | 52.2 | 10.6 | 18.6 |
| Test 44 | 94.7 | 99.1 | 0.09 | 0.20 | 0.11 | 0.02 | 0.02 | 0.01 | 0.01 | 0.14 | 99.70 | 95.0 | 42.6 | 61.3 |
| Test 45 | 93.0 | 98.9 | 0.06 | 0.09 | 0.06 | 0.01 | 0.01 | 0.01 | 0.01 | 0.13 | 99.28 | 93.1 | 27.9 | 32.8 |
| Test 46 | 90.4 | 98.9 | 0.07 | 0.03 | 0.04 | 0.01 | 0.01 | 0.01 | 0.02 | 0.25 | 99.34 | 90.5 | 31.6 | 21.3 |
| Test 48 | 92.8 | 98.8 | 0.04 | 0.02 | 0.06 | 0.01 | 0.01 | 0.01 | 0.01 | 0.12 | 99.08 | 92.8 | 18.6 | 32.8 |
| Test 49 | 83.7 | 99.0* | 0.03 | 0.02 | 0.07 | 0.01 | 0.01 | 0.01 | 0.01 | 0.13 | 99.29 | 83.9 | 12.6 | 34.5 |

* Estimated
**Calculated by difference

TABLE 6. Continued

| Products | Wt % | Analysis % | | | | | | | | | | Distribution % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | TOTAL | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| **Sample C** | | | | | | | | | | | | | | |
| Head sample | 100.00 | 95.68 | 0.23 | 0.08 | 2.51 | 0.02 | 0.12 | 0.18 | 0.11 | 1.04 | 99.97 | 100.0 | 100.0 | 100.0 |
| Screening | | | | | | | | | | | | | | |
| +420 µm | 64.9 | | | | | | | | | | | | | |
| -420 µm | 35.1 | 89.5† | 0.66 | 0.58 | 6.47 | 0.06 | 0.36 | 0.21 | 0.25 | 1.65† | 99.74 | 32.1 | 100.0 | 90.5 |
| Attrition Scrubbing* | | | | | | | | | | | | | | |
| -420 +100 µm | 18.1 | 98.0 | 0.28 | 0.30 | 0.55 | 0.02 | 0.06 | 0.02 | 0.06 | 0.27 | 99.56 | 18.5 | 22.0 | 4.0 |
| -100 µm | 17.0 | | | | | | | | | | | | | |
| Magnetic Separation | | | | | | | | | | | | | | |
| Wet (Sala) | 17.4 | 99.29 | 0.06 | 0.04 | 0.19 | 0.01 | 0.02 | 0.01 | 0.03 | 0.14 | 99.79 | 18.1 | 4.5 | 1.3 |
| Dry (Exolon)** | 17.3 | 99.33 | 0.03 | 0.03 | 0.21 | 0.01 | 0.02 | 0.02 | 0.04 | 0.16 | 99.85 | 18.0 | 2.3 | 1.5 |
| Flotation Concns | | | | | | | | | | | | | | |
| Test 16 | 15.9 | 99.46 | 0.08 | 0.03 | 0.13 | 0,02 | 0.02 | 0.01 | 0.01 | 0.13 | 99.89 | 16.5 | 5.5 | 0.8 |
| Test 17 | 18.0 | 98.52 | 0.23 | 0.15 | 0.50 | 0.02 | 0.05 | 0.01 | 0.01 | 0.19 | 99.68 | 18.5 | 18.0 | 3.6 |
| Test 18 | 17.2 | 99.52 | 0.04 | 0.01 | 0.08 | 0.02 | 0.01 | 0.01 | 0.01 | 0.12 | 99.82 | 17.9 | 3.0 | 0.6 |
| Test 19 | 16.4 | 99.53 | 0.03 | 0.01 | 0.07 | 0.02 | 0.01 | 0.01 | 0.01 | 0.14 | 99.83 | 17.1 | 2.1 | 0.5 |

* Attrition scrubbing was conducted for only 15 min
**Conducted on unscrubbed material
† Calculated by difference

TABLE 6. Continued

| Products | Wt % | Analysis % | | | | | | | | | Distribution % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | TOTAL | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| Sample D | | | | | | | | | | | | | | |
| Head sample | 100.00 | 88.67 | 0.40 | 0.06 | 2.95 | 1.04* | 0.74* | 0.30 | 3.19 | 2.66 | 100.01 | 100.0 | 100.0 | 100.0 |
| Screening | | | | | | | | | | | | | | |
| +630 µm | 3.0 | | | | | | | | | | | | | |
| -630 µm | 97.0 | 89.0** | 0.30 | 0.04 | 2.77 | 1.04 | 0.74 | 0.26 | 3.03 | 2.33 | 99.51 | 97.4 | 72.8 | 91.1 |
| Attrition Scrubbing | | | | | | | | | | | | | | |
| -630 +100 µm | 86.0 | 89.2** | 0.35 | 0.04 | 2.79 | 1.11 | 0.77 | 0.24 | 2.99 | 2.47 | 99.96 | 86.5 | 75.3 | 81.3 |
| -100 µm | 11.0 | | | | | | | | | | | | | |
| Magnetic Separation | | | | | | | | | | | | | | |
| Wet (Sala) | 73.9 | 91.3** | 0.08 | 0.01 | 2.92 | 0.78 | 0.59 | 0.10 | 2.24 | 1.66 | 99.68 | 76.1 | 14.8 | 73.2 |
| Dry (Exolon) | 82.0 | 91.2** | 0.09 | 0.01 | 2.26 | 0.89 | 0.63 | 0.10 | 2.66 | 2.18 | 100.02 | 84.3 | 18.5 | 62.8 |
| Flotation Concns | | | | | | | | | | | | | | |
| Test 10 | 83.4 | 94.10 | 0.23 | 0.03 | 3.00 | 1.14* | 0.77* | 0.12 | 0.76 | 0.31 | 99.95 | 88.5 | 48.0 | 84.8 |
| Test 12 | 80.0 | 93.33 | 0.17 | 0.02 | 2.83 | 1.14* | 0.77* | 0.13 | 1.12 | 0.59 | 100.10 | 84.2 | 34.0 | 76.8 |
| Test 21 | 28.3 | 93.33 | 0.08 | 0.01 | 2.78 | 1.14 | 0.77 | 0.10 | 0.58 | 0.29 | 99.05 | 29.8 | 5.7 | 26.7 |
| Test 22 | 80.8 | 93.2** | 0.08 | 0.01 | 2.26 | 1.02 | 0.66 | 0.10 | 1.58 | 1.07 | 99.98 | 84.9 | 16.2 | 61.9 |
| Test 23 | 79.2 | 93.0** | 0.08 | 0.01 | 2.24 | 1.01 | 0.65 | 0.10 | 1.57 | 1.11 | 99.77 | 83.1 | 18.4 | 60.1 |

* Estimated
**Calculated by difference

TABLE 6. Continued

| Products | Wt % | Analysis % | | | | | | | | | | Distribution % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | TOTAL | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| **Sample E** | | | | | | | | | | | | | | |
| Head sample | 100.00 | 97.21 | 0.39 | 0.11 | 1.01 | 0.09 | 0.14 | 0.14 | 0.49 | 0.37 | 99.95 | 100.0 | 100.0 | 100.0 |
| Screening | | | | | | | | | | | | | | |
| +630 µm | 0.1 | | | | | | | | | | | | | |
| -630 µm | 99.9 | 97.21 | 0.39 | 0.11 | 1.01 | 0.09 | 0.14 | 0.14 | 0.49 | 0.37 | 99.95 | 99.9 | 99.9 | 99.9 |
| Attrition Scrubbing | | | | | | | | | | | | | | |
| -630 +100 µm | 93.0 | 99.1* | 0.08 | 0.10 | 0.20 | 0.02 | 0.09 | 0.01 | 0.03 | 0.18 | 99.81 | 94.8 | 19.1 | 18.4 |
| -100 µm | 6.9 | | | | | | | | | | | | | |
| Magnetic Separation | | | | | | | | | | | | | | |
| Wet (Sala) | 87.1 | 99.3* | 0.06 | 0.02 | 0.24 | 0.02 | 0.10 | 0.01 | 0.02 | 0.18 | 99.95 | 89.0 | 13.4 | 20.7 |
| Dry (Exolon) | 90.9 | 99.3* | 0.04 | 0.03 | 0.16 | 0.14 | 0.10 | 0.01 | 0.02 | 0.10 | 99.90 | 92.9 | 9.3 | 14.4 |
| Flotation Concns | | | | | | | | | | | | | | |
| Test 24 | 68.5 | 99.48 | 0.05 | 0.02 | 0.04 | 0.11 | 0.02 | 0.01 | 0.01 | 0.18 | 99.92 | 70.1 | 8.8 | 2.7 |
| Test 25 | 51.4 | 99.50 | 0.06 | 0.02 | 0.09 | 0.01 | 0.03 | 0.01 | 0.01 | 0.17 | 99.90 | 52.6 | 7.9 | 4.6 |
| Test 26 | 89.8 | 99.46 | 0.05 | 0.02 | 0.11 | 0.02 | 0.08 | 0.01 | 0.01 | 0.16 | 99.92 | 91.9 | 11.5 | 9.8 |
| Test 27 | 17.1 | 99.47 | 0.05 | 0.02 | 0.08 | 0.01 | 0.04 | 0.01 | 0.02 | 0.19 | 99.89 | 17.5 | 2.2 | 1.4 |
| Test 28 | 56.0 | 99.51 | 0.05 | 0.01 | 0.04 | 0.01 | 0.03 | 0.01 | 0.01 | 0.16 | 99.83 | 57.3 | 7.2 | 2.2 |
| Test 31 | 69.5 | 99.3* | 0.08 | 0.02 | 0.06 | 0.01 | 0.03 | 0.08 | 0.03 | 0.22 | 99.83 | 71.0 | 14.3 | 4.1 |

*Calculated by difference

TABLE 6. Continued

| Products | Wt % | Analysis % | | | | | | | | | | Distribution % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | TOTAL | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| Sample F | | | | | | | | | | | | | | |
| Head sample | 100.00 | 98.8 | 0.16 | 0.08 | 0.41 | 0.01 | 0.02 | 0.10 | 0.01 | 0.30 | 99.90 | 100.0 | 100.0 | 100.0 |
| Screening | | | | | | | | | | | | | | |
| +630 µm | - | | | | | | | | | | | | | |
| -630 µm | 100.0** | 98.8 | 0.16 | 0.08 | 0.41 | 0.01 | 0.02 | 0.10 | 0.01 | 0.30 | 99.90 | 100.0 | 100.0 | 100.0 |
| Attrition Scrubbing | | | | | | | | | | | | | | |
| -630 +100 µm | 88.3 | 99.0* | 0.17 | 0.07 | 0.11 | 0.02 | 0.01 | 0.10 | 0.01 | 0.20 | 99.69 | 88.5 | 93.8 | 23.7 |
| -100 µm | 11.7 | | | | | | | | | | | | | |
| Magnetic Separation | | | | | | | | | | | | | | |
| Wet (Sala) | 82.6 | 98.9* | 0.06 | 0.02 | 0.23 | 0.02 | 0.01 | 0.01 | 0.04 | 0.30 | 99.59 | 82.7 | 31.0 | 46.3 |
| Dry (Exolon) | 86.7 | 98.9 | 0.07 | 0.04 | 0.16 | 0.02 | 0.01 | 0.01 | 0.02 | 0.20 | 99.40 | 86.8 | 37.9 | 33.8 |
| Flotation Concns | | | | | | | | | | | | | | |
| Test 13 | 43.0 | 99.14 | 0.07 | 0.03 | 0.28 | 0.01 | 0.01 | 0.02 | 0.04 | 0.23 | 99.81 | 43.2 | 18.8 | 29.4 |
| Test 29 | 85.8 | 98.82 | 0.05 | 0.03 | 0.09 | 0.01 | 0.01 | 0.02 | 0.01 | 0.20 | 99.24 | 85.8 | 26.8 | 18.8 |
| Test 30 | 81.9 | 99.0* | 0.07 | 0.03 | 0.07 | 0.01 | 0.01 | 0.02 | 0.02 | 0.24 | 99.47 | 81.2 | 35.8 | 14.0 |
| Test 35 | 86.9 | 98.8* | 0.07 | 0.04 | 0.20 | 0.01 | 0.01 | 0.02 | 0.01 | 0.21 | 99.37 | 86.9 | 38.0 | 42.4 |
| Test 36 | 85.0 | 98.8* | 0.09 | 0.03 | 0.05 | 0.01 | 0.01 | 0.02 | 0.01 | 0.20 | 99.22 | 85.0 | 47.8 | 10.4 |

* Calculated by difference

**Oversize (+630 µm) grains were mainly weakly clay bonded smaller sand grains

TABLE 6. Continued

| Products | Wt % | Analysis % | | | | | | | | | | Distribution % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | TOTAL | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| Sample G | | | | | | | | | | | | | | |
| Head sample | 100.00 | 98.2* | 0.06 | 0.14 | 0.67 | 0.01 | 0.21 | 0.03 | 0.01 | 0.27 | 99.60 | 100.0 | 100.0 | 100.0 |
| Screening | | | | | | | | | | | | | | |
| +630 µm | - | | | | | | | | | | | | | |
| -630 µm | 100.0 | 98.2* | 0.06 | 0.14 | 0.67 | 0.01 | 0.21 | 0.03 | 0.01 | 0.27 | 99.60 | 100.0 | 100.0 | 100.0 |
| Attrition Scrubbing | | | | | | | | | | | | | | |
| -630 +100 µm | 92.4 | 98.6* | 0.05 | 0.12 | 0.35 | 0.01 | 0.28 | 0.03 | 0.01 | 0.13 | 99.58 | 92.8 | 77.0 | 48.3 |
| -100 µm | 7.6 | | | | | | | | | | | | | |
| Magnetic Separation | | | | | | | | | | | | | | |
| Wet (Sala) | 87.4 | 98.8 | 0.05 | 0.02 | 0.53 | 0.01 | 0.29 | 0.01 | 0.03 | 0.24 | 99.98 | 87.9 | 72.8 | 69.1 |
| Dry (Exolon) | 91.2 | 99.0 | 0.04 | 0.01 | 0.31 | 0.01 | 0.11 | 0.03 | 0.01 | 0.13 | 99.65 | 91.9 | 60.8 | 42.2 |
| Flotation Concns | | | | | | | | | | | | | | |
| Test 53 | 85.0 | 99.0 | 0.05 | 0.02 | 0.24 | 0.01 | 0.12 | 0.03 | 0.01 | 0.13 | 99.61 | 85.7 | 70.8 | 30.5 |
| Test 54 | 33.3 | 98.3 | 0.04 | 0.04 | 0.58 | 0.02 | 0.36 | 0.03 | 0.01 | 0.14 | 99.52 | 33.3 | 22.2 | 28.8 |
| Test 55 | 38.4 | 98.6* | 0.03 | 0.03 | 0.45 | 0.01 | 0.31 | 0.03 | 0.01 | 0.14 | 99.61 | 38.6 | 19.2 | 25.8 |
| Test 56 | 92.0 | 98.8 | 0.04 | 0.07 | 0.28 | 0.01 | 0.12 | 0.03 | 0.01 | 0.15 | 99.51 | 92.6 | 61.3 | 61.6 |
| Test 57 | 88.0 | 99.0* | 0.03 | 0.03 | 0.16 | 0.01 | 0.07 | 0.03 | 0.01 | 0.12 | 99.46 | 88.7 | 44.0 | 21.0 |
| Test 60 | 90.6 | 99.0* | 0.02 | 0.01 | 0.26 | 0.01 | 0.10 | 0.03 | 0.01 | 0.13 | 99.57 | 91.3 | 30.2 | 35.2 |
| Test 61 | 67.4 | 99.2* | 0.03 | 0.01 | 0.08 | 0.01 | 0.03 | 0.03 | 0.01 | 0.19 | 99.59 | 68.1 | 33.7 | 8.1 |
| Test 62 | 89.0 | 99.0 | 0.03 | 0.01 | 0.19 | 0.01 | 0.08 | 0.03 | 0.01 | 0.15 | 99.51 | 89.7 | 44.5 | 25.2 |

*Calculated by difference

TABLE 6. Continued

| Products | Wt % | Analysis % | | | | | | | | | | Distribution % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | TOTAL | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| Sample H | | | | | | | | | | | | | | |
| Head sample | 100.00 | 98.0* | 0.09 | 0.06 | 0.78 | 0.02 | 0.23 | 0.02 | 0.02 | 0.34 | 99.56 | 100.0 | 100.0 | 100.0 |
| Screening | | | | | | | | | | | | | | |
| +630 µm | - | | | | | | | | | | | | | |
| -630 µm | 100.0 | 98.0* | 0.09 | 0.06 | 0.78 | 0.02 | 0.23 | 0.02 | 0.02 | 0.34 | 99.56 | 100.0 | 100.0 | 100.0 |
| Attrition Scrubbing | | | | | | | | | | | | | | |
| -630 +100 µm | 88.6 | 98.4* | 0.07 | 0.06 | 0.41 | 0.02 | 0.24 | 0.02 | 0.03 | 0.13 | 99.38 | 89.0 | 68.9 | 46.6 |
| -100 µm | 11.4 | | | | | | | | | | | | | |
| Magnetic Separation | | | | | | | | | | | | | | |
| Wet (Sala) | 80.3 | 98.5* | 0.06 | 0.02 | 0.53 | 0.01 | 0.17 | 0.01 | 0.03 | 0.27 | 99.60 | 80.7 | 53.5 | 54.6 |
| Dry (Exolon) | 88.2 | 98.5 | 0.05 | 0.01 | 0.34 | 0.01 | 0.16 | 0.02 | 0.01 | 0.17 | 99.27 | 88.7 | 49.0 | 38.5 |
| Flotation Concns | | | | | | | | | | | | | | |
| Test 63 | 81.5 | 99.0* | 0.03 | 0.01 | 0.32 | 0.01 | 0.12 | 0.02 | 0.01 | 0.18 | 99.70 | 82.3 | 27.2 | 33.4 |
| Test 64 | 88.0 | 99.0* | 0.04 | 0.04 | 0.33 | 0.02 | 0.18 | 0.02 | 0.01 | 0.20 | 99.84 | 88.9 | 39.1 | 37.2 |
| Test 65 | 80.5 | 99.1* | 0.08 | 0.03 | 0.20 | 0.01 | 0.12 | 0.02 | 0.01 | 0.22 | 99.79 | 81.4 | 71.6 | 20.6 |
| Test 66 | 62.2 | 99.2* | 0.04 | 0.02 | 0.14 | 0.01 | 0.09 | 0.02 | 0.01 | 0.20 | 99.73 | 63.0 | 27.6 | 11.2 |
| Test 68 | 81.4 | 99.2* | 0.03 | 0.01 | 0.21 | 0.01 | 0.11 | 0.02 | 0.01 | 0.14 | 99.74 | 82.4 | 27.1 | 21.9 |

*Calculated by difference

TABLE 6. Continued

| Products | Wt % | Analysis % | | | | | | | | | | Distribution % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | TOTAL | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| Sample I | | | | | | | | | | | | | | |
| Head sample | 100.00 | 69.7* | 3.24 | 0.52 | 13.20 | 4.10 | 1.00 | 1.36 | 5.81 | 1.05 | 99.98 | 100.0 | 100.0 | 100.0 |
| Screening | | | | | | | | | | | | | | |
| +630 µm | 5.3 | | | | | | | | | | | | | |
| -630 µm | 94.7 | 70.0* | 2.77 | 0.42 | 13.10 | 4.18 | 1.02 | 1.17 | 5.54 | 1.03 | 99.23 | 95.1 | 81.0 | 94.0 |
| Attrition Scrubbing | | | | | | | | | | | | | | |
| -630 +100 µm | 94.1 | 70.3* | 3.03 | 0.52 | 13.20 | 4.15 | 0.98 | 1.27 | 5.81 | 0.82 | 100.08 | 94.9 | 88.0 | 94.1 |
| -100 µm | 0.6 | | | | | | | | | | | | | |
| Magnetic Separation | | | | | | | | | | | | | | |
| Wet (Sala) | 34.5 | 78.0 | 0.14 | 0.01 | 12.10 | 3.80 | 0.90 | 0.03 | 3.70 | 0.34 | 99.02 | 38.6 | 1.5 | 31.6 |
| Dry (Exolon) | 55.8 | 78.3 | 0.18 | 0.03 | 12.10 | 4.15 | 0.98 | 0.03 | 3.72 | 0.30 | 99.79 | 62.7 | 3.1 | 51.2 |
| Flotation Concns | | | | | | | | | | | | | | |
| Test 50 | 93.5 | 73.3 | 3.03 | 0.64 | 12.50 | 4.43 | 0.96 | 1.27 | 2.95 | 0.83 | 99.92 | 98.3 | 87.4 | 88.5 |
| Test 51 | 92.3 | 73.1 | 3.07 | 0.69 | 12.80 | 4.40 | 1.01 | 1.22 | 2.97 | 0.80 | 100.07 | 96.8 | 87.5 | 89.5 |
| Test 52 | 55.7 | 79.0 | 0.17 | 0.03 | 11.60 | 4.50 | 1.01 | 0.03 | 2.77 | 0.32 | 99.43 | 63.1 | 2.9 | 49.0 |

*Calculated by difference

TABLE 7. Flotation reagent concentration

| Sample | Test No. | Iron Oxide Float | | Alumino-silicate Float | |
|---|---|---|---|---|---|
| | | % weight floated | Aero 840 g/tonne | % weight floated | Duomeen TDO g/tonne |
| A | 32 | 63.1 | 124 | - | - |
| | 33 | 27.3 | 77 | 2.6 | 128 |
| | 37 | - | - | 5.5 | 127 |
| | 38 | - | - | 15.4 | 250 |
| | 41 | - | - | 3.5 | 126 |
| | 42 | - | - | 10.5 | 253 |
| B | 43 | 44.0 | 126 | 1.2 | 126 |
| | 44 | - | - | 1.9 | 126 |
| | 45 | 1.6 | 76 | 2.2 | 126 |
| | 46 | - | - | 6.3 | 252 |
| | 48 | - | - | 2.2 | 127 |
| | 49 | - | - | 11.8 | 251 |
| C | 16 | 11.6 | 127 | 0.6 | 127 |
| | 17 | - | - | 0.6 | 126 |
| | 18 | - | - | 0.6 | 188 |
| | 19 | - | - | 5.2 | 325 |
| D | 10 | 0.4 | 135 | 2.7 | 135 |
| | 12* | 1.5 | 131 | 1.6 | 131 |
| | 22 | - | - | 1.5 | 127 |
| | 23 | - | - | 3.4 | 248 |
| E | 24 | 10.0 | 120 | 16.3 | 120 |
| | 25 | 31.8 | 80 | 12.9 | 80 |
| | 26 | - | - | 1.2 | 125 |
| | 34 | - | - | - | 125 |
| | 27 | - | - | 81.2 | 252 |
| | 28 | - | - | 38.4 | 176 |
| | 31 | - | - | 23.5 | 151 |
| F | 13 | 51.3 | 126 | - | - |
| | 29 | - | - | 1.0 | 126 |
| | 30 | - | - | 5.5 | 251 |
| | 35 | - | - | 1.6 | 126 |
| | 36 | - | - | 3.7 | 249 |

TABLE 7. Continued

| Sample | Test No. | Iron Oxide Float | | Alumino-silicate Float | |
|---|---|---|---|---|---|
| | | % weight floated | Aero 840 g/tonne | % weight floated | Duomeen TDO g/tonne |
| G | 53 | 6.4 | 124 | 1.6 | 124 |
| | 54 | 64.0 | 254 | - | - |
| | 55 | 58.4 | 188 | - | - |
| | 56 | - | - | 0.4 | 125 |
| | 57 | - | - | 4.8 | 185 |
| | 58 | - | - | 63.0 | 251 |
| | 60 | - | - | 0.7 | 125 |
| | 61 | - | - | 26.1 | 252 |
| | 62 | - | - | 2.4 | 190 |
| H | 63 | 7.0 | 125 | 1.0 | 125 |
| | 64 | - | - | 0.7 | 129 |
| | 65 | - | - | 9.1 | 252 |
| | 66 | 14.5 | 171 | 15.4 | 171 |
| | 68 | 4.4 | 121 | 3.7 | 243 |
| I | 50 | 0.3 | 126 | 0.3 | 126 |
| | 51 | 1.0 | 253 | 1.0 | 127 |
| | 52 | - | - | 0.2 | 251 |

*A calcite float was conducted before the iron oxide float

TABLE 8. Product balances of the best tests obtained with each sample employing flotation only

| Sample | Test | Products | Wt % | Analysis % | | Distribution % | |
|---|---|---|---|---|---|---|---|
| | | | | $Al_2O_3$ | $Fe_2O_3$ | $Al_2O_3$ | $Fe_2O_3$ |
| A | 38 | Alumino-silicate float | 13.1 | 0.71 | 1.41 | 68.2 | 86.5 |
| | | Quartz concentrate | 72.2 | 0.06 | 0.04 | 31.8 | 13.5 |
| | | Calculated head | 85.3 | 0.16 | 0.25 | 100.0 | 100.0 |
| B | 45 | Iron oxide float | 1.5 | 3.00 | 6.71 | 37.8 | 54.7 |
| | | Alumino-silicate float | 2.1 | 0.87 | 1.32 | 15.4 | 15.0 |
| | | Quartz concentrate | 93.0 | 0.06 | 0.06 | 46.8 | 30.3 |
| | | Calculated head | 96.6 | 0.12 | 0.18 | 100.0 | 100.0 |
| C | 16 | Iron oxide float | 2.1 | 2.54 | 1.60 | 67.8 | 68.9 |
| | | Alumino silicate float | 0.1 | 4.55 | 2.47 | 5.9 | 5.1 |
| | | Quartz concentrate | 15.9 | 0.13 | 0.08 | 26.3 | 26.0 |
| | | Calculated head | 18.1 | 0.43 | 0.27 | 100.0 | 100.0 |
| D | 10 | Iron oxide float | 0.3 | 6.54 | 9.07 | 0.9 | 13.0 |
| | | Alumino-silicate float | 2.3 | 2.97 | 0.71 | 2.7 | 6.9 |
| | | Quartz concentrate | 83.4 | 3.00 | 0.23 | 96.4 | 80.1 |
| | | Calculated head | 86.0 | 3.01 | 0.28 | 100.0 | 100.0 |
| E | 24 | Iron oxide float | 9.3 | 0.47 | 0.23 | 21.8 | 30.8 |
| | | Alumino-silicate float | 15.2 | 0.85 | 0.09 | 64.5 | 19.7 |
| | | Quartz concentrate | 68.5 | 0.04 | 0.05 | 13.7 | 49.5 |
| | | Calculated head | 93.0 | 0.22 | 0.08 | 100.0 | 100.0 |
| F | 36 | Alumino-silicate float | 3.3 | 0.86 | 0.29 | 40.1 | 11.2 |
| | | Quartz concentrate | 85.0 | 0.05 | 0.09 | 59.9 | 88.8 |
| | | Calculated head | 88.3 | 0.07 | 0.10 | 100.0 | 100.0 |
| G | 57 | Alumino-silicate float | 4.4 | 2.59 | 0.62 | 44.7 | 50.8 |
| | | Quartz concentrate | 88.0 | 0.16 | 0.03 | 55.3 | 49.2 |
| | | Calculated head | 92.4 | 0.28 | 0.06 | 100.0 | 100.0 |

TABLE 8. Continued

| Sample | Test | Products | Wt % | Analysis % | | Distribution % | |
|---|---|---|---|---|---|---|---|
| | | | | $Al_2O_3$ | $Fe_2O_3$ | $Al_2O_3$ | $Fe_2O_3$ |
| H | 66 | Iron oxide float | 12.8 | 0.48 | 0.13 | 17.0 | 32.6 |
| | | Alumino-silicate float | 13.6 | 1.57 | 0.07 | 58.9 | 18.6 |
| | | Quartz concentrate | 62.2 | 0.14 | 0.04 | 24.1 | 48.8 |
| | | Calculated head | 88.6 | 0.41 | 0.06 | 100.0 | 100.0 |
| I | 50 | Iron oxide float | 0.3 | 13.0 | 3.30 | 0.3 | 0.4 |
| | | Alumino-silicate float | 0.3 | 12.7 | 4.07 | 0.3 | 0.4 |
| | | Quartz concentrate | 93.5 | 12.5 | 3.03 | 99.4 | 99.2 |
| | | Calculated head | 94.1 | 12.5 | 3.03 | 100.00 | 100.0 |

TABLE 9. Product balances of the best tests obtained with each sample employing both magnetic separation and flotation

| Sample | Test | Products | Wt % | Analysis % | | Distribution % | |
|---|---|---|---|---|---|---|---|
| | | | | $Al_2O_3$ | $Fe_2O_3$ | $Al_2O_3$ | $Fe_2O_3$ |
| A | 42 | Exolon non-magnetics | 82.7 | 0.14 | 0.04 | 68.1 | 16.5 |
| | | Alumino-silicate float | 8.7 | 0.31 | 0.07 | 21.0 | 2.8 |
| | | Quartz concentrate | 74.0 | 0.08 | 0.04 | 47.1 | 13.7 |
| | | Calculated head | 82.7 | 0.11 | 0.04 | 68.1 | 16.5 |
| B | 49 | Exolon non-magnetics | 94.9 | 0.09 | 0.04 | 50.2 | 19.0 |
| | | Alumino-silicate float | 11.2 | 0.20 | 0.04 | 13.9 | 2.8 |
| | | Quartz concentrate | 83.7 | 0.07 | 0.03 | 36.3 | 16.2 |
| | | Calculated head | 94.9 | 0.09 | 0.03 | 50.2 | 19.0 |
| C | 19 | Exolon non-magnetics | 17.3 | 0.21 | 0.03 | 1.5 | 2.3 |
| | | Alumino-silicate float | 0.9 | 1.61 | 0.08 | 0.8 | 0.3 |
| | | Quartz concentrate | 16.4 | 0.07 | 0.03 | 0.7 | 2.0 |
| | | Calculated head | 17.3 | 0.15 | 0.03 | 1.5 | 2.3 |
| D | 23 | Exolon non-magnetics | 82.0 | 2.26 | 0.09 | 62.8 | 18.5 |
| | | Alumino-silicate float | 2.8 | 1.88 | 0.43 | 1.8 | 2.9 |
| | | Quartz concentrate | 79.2 | 2.24 | 0.08 | 61.0 | 15.6 |
| | | Calculated head | 82.0 | 2.23 | 0.09 | 62.8 | 18.5 |
| E | 26 | Exolon non-magnetics | 90.9 | 0.16 | 0.04 | 14.4 | 9.3 |
| | | Alumino-silicate float | 1.1 | 2.18 | 0.08 | 2.8 | 0.2 |
| | | Quartz concentrate | 89.8 | 0.11 | 0.05 | 11.6 | 9.1 |
| | | Calculated head | 90.9 | 0.14 | 0.05 | 14.4 | 9.3 |
| F | 29 | Exolon non-magnetics | 86.7 | 0.16 | 0.07 | 33.8 | 37.9 |
| | | Alumino-silicate float | 0.9 | 0.78 | 0.08 | 2.8 | 0.6 |
| | | Quartz concentrate | 85.8 | 0.09 | 0.05 | 31.0 | 37.3 |
| | | Calculated head | 86.7 | 0.10 | 0.05 | 33.8 | 37.9 |

TABLE 9. Continued

| Sample | Test | Products | Wt % | Analysis % | | Distribution % | |
|---|---|---|---|---|---|---|---|
| | | | | $Al_2O_3$ | $Fe_2O_3$ | $Al_2O_3$ | $Fe_2O_3$ |
| G | 61 | Exolon non-magnetics | 91.2 | 0.31 | 0.04 | 42.2 | 60.8 |
| | | Alumino-silicate float | 23.8 | 0.76 | 0.04 | 32.5 | 19.5 |
| | | Quartz concentrate | 67.4 | 0.08 | 0.03 | 9.7 | 41.3 |
| | | Calculated head | 91.2 | 0.26 | 0.03 | 42.2 | 60.8 |
| I | 52 | Exolon non-magnetics | 55.8 | 12.10 | 0.18 | 51.2 | 3.10 |
| | | Alumino-silicate float | 0.1 | 11.6 | 0.17 | 0.1 | - |
| | | Quartz concentrate | 55.7 | 11.6 | 0.17 | 51.1 | 3.10 |
| | | Calculated head | 55.8 | 11.6 | 0.17 | 51.2 | 3.10 |

TABLE 10. Sala wet magnetic separation test

| | Wt % | Analysis % $Fe_2O_3$ | Distribution % |
|---|---|---|---|
| Sample A | | | |
| Magnetics | 10.9 | 1.54 | 84.9 |
| Non-magnetics | 74.4 | 0.04 | 15.1 |
| Calculated head | 85.3 | 0.23 | 100.0 |
| Sample B | | | |
| Magnetics | 9.2 | 1.65 | 81.3 |
| Non-magnetics | 87.3 | 0.04 | 18.7 |
| Calculated head | 96.5 | 0.19 | 100.0 |
| Sample C | | | |
| Magnetics | 0.7 | 5.26 | 78.0 |
| Non-magnetics | 17.4 | 0.06 | 22.0 |
| Calculated head | 18.1 | 0.26 | 100.0 |
| Sample D | | | |
| Magnetics | 12.1 | 2.33 | 82.7 |
| Non-magnetics | 73.9 | 0.08 | 17.3 |
| Calculated head | 86.0 | 0.40 | 100.0 |
| Sample E | | | |
| Magnetics | 5.9 | 0.68 | 43.4 |
| Non-magnetics | 87.1 | 0.06 | 56.6 |
| Calculated head | 93.0 | 0.11 | 100.0 |
| Sample F | | | |
| Magnetics | 5.7 | 1.44 | 62.3 |
| Non-magnetics | 82.6 | 0.06 | 37.7 |
| Calculated head | 88.3 | 0.15 | 100.0 |
| Sample G* | | | |
| Magnetics | 5.4 | 0.79 | 47.4 |
| Non-magnetics | 94.6 | 0.05 | 52.6 |
| Calculated head | 100.0 | 0.09 | 100.0 |

TABLE 10. Continued

| | Wt % | Analysis % $Fe_2O_3$ | Distribution % |
|---|---|---|---|
| Sample H* | | | |
| Magnetics | 6.3 | 0.46 | 44.2 |
| Non-magnetics | 61.0 | 0.06 | 55.8 |
| Calculated head | 67.3 | 0.10 | 100.0 |
| Sample I | | | |
| Magnetics | 59.6 | 4.89 | 98.4 |
| Non-magnetics | 34.5 | 0.14 | 1.6 |
| Calculated head | 94.1 | 3.15 | 100.0 |

*Based on an earlier, smaller sample

TABLE 11. Exolon dry magnetic separation tests

| | Wt % | Analysis % $Fe_2O_3$ | Distribution % |
|---|---|---|---|
| Sample A | | | |
| Magnetics | 1.0 | 16.25 | 80.9 |
| Middlings | 1.6 | 0.33 | 2.6 |
| Non-magnetics | 82.7 | 0.04 | 16.5 |
| Calculated head | 85.3 | 0.24 | 100.0 |
| Sample B | | | |
| Magnetics | 0.9 | 16.40 | 78.5 |
| Middlings | 0.8 | 0.34 | 1.4 |
| Non-magnetics | 94.8 | 0.04 | 20.1 |
| Calculated head | 96.5 | 0.20 | 100.0 |
| Sample C | | | |
| Magnetics | 0.3 | 11.28 | 80.5 |
| Middlings | 0.2 | 0.13 | 0.7 |
| Non-magnetics | 17.6 | 0.05 | 18.8 |
| Calculated head | 18.1 | 0.23 | 100.0 |
| Sample D | | | |
| Magnetics | 3.1 | 4.74 | 63.2 |
| Middlings | 1.0 | 1.02 | 4.4 |
| Non-magnetics | 81.9 | 0.09 | 32.4 |
| Calculated head | 86.0 | 0.27 | 100.0 |
| Sample E | | | |
| Magnetics | 0.8 | 3.33 | 39.7 |
| Middlings | 1.3 | 0.31 | 6.0 |
| Non-magnetics | 90.9 | 0.04 | 54.3 |
| Calculated head | 93.0 | 0.07 | 100.0 |
| Sample F | | | |
| Magnetics | 0.6 | 9.75 | 48.1 |
| Middlings | 1.0 | 0.24 | 2.0 |
| Non-magnetics | 86.7 | 0.07 | 49.9 |
| Calculated head | 88.3 | 0.14 | 100.0 |

TABLE 11. Continued

| | Wt % | Analysis % $Fe_2O_3$ | Distribution % |
|---|---|---|---|
| Sample G | | | |
| Magnetics | 0.3 | 6.64 | 34.9 |
| Middlings | 0.9 | 0.07 | 1.1 |
| Non-magnetics | 91.2 | 0.05 | 64.0 |
| Calculated head | 92.4 | 0.06 | 100.0 |
| Sample H | | | |
| Magnetics | 0.2 | 6.06 | 21.4 |
| Middlings | 0.2 | 0.16 | 0.5 |
| Non-magnetics | 88.2 | 0.05 | 78.1 |
| Calculated head | 88.6 | 0.06 | 100.0 |
| Sample I | | | |
| Magnetics | 28.9 | 8.28 | 89.0 |
| Middlings | 9.4 | 2.10 | 7.3 |
| Non-magnetics | 55.8 | 0.18 | 3.7 |
| Calculated head | 94.1 | 2.86 | 100.0 |

TABLE 12. Electrostatic separation tests

| Sample | Products | Wt % | Analysis % $Al_2O_3$ | Distribution % |
|---|---|---|---|---|
| D | Pinned fraction | 59.3 | 2.96 | 65.7 |
| | Middling | 25.1 | 2.28 | 21.5 |
| | Thrown fraction | 15.6 | 2.18 | 12.8 |
| | Calculated head | 100.0 | 2.67 | 100.0 |
| I | Pinned fraction | 67.9 | 11.9 | 68.2 |
| | Middling | 11.7 | 13.4 | 13.3 |
| | Thrown fraction | 20.4 | 10.7 | 18.5 |
| | Calculated head | 100.0 | 11.8 | 100.0 |

TABLE 13. Mechanical properties of sand/clay/water mixtures

| | SAMPLE IDENTIFICATION | | | | | | |
|---|---|---|---|---|---|---|---|
| | Ottawa silica (typical) | B | C | D | E | G | H |
| AFS No. | 60 | 54 | - | 64 | 80 | 60 | 42 |
| Sand quantity, kg | - | 10 | 10 | 10 | 10 | 5 | 5 |
| Clay (bentonite) g | 6.5%* | 650 | 650 | 650 | 650 | 325 | 325 |
| Cereal, g | 1.5%* | 100 | 100 | 100 | 100 | 50 | 50 |
| Moisture %** | 3.3 | 3.1 | 3.0 | 2.5 | 3.1 | 3.0 | 3.0 |
| Permeability (air)** | 180-225 | 183 | 157- | 129 | 80 | 141 | 288 |
| Mouldability index** | 70-76 | 75 | 87 | 83 | 62 | 57 | 73 |
| Green compression kPa** | 59-69 | 45 | 46 | 68 | 48 | 50 | 47 |
| Green shear kPa** | 1.0-1.4 | 1.0 | 0.9 | 1.3 | 1.0 | 1.1 | 1.0 |
| Green tensile kPa** | 5.6-8.6 | 6.7 | 4.6 | 9.7 | 5.9 | 1.5 | 1.5 |
| Dry compression, kPa** | 359-565 | 228 | 124 | 166 | 166 | 301 | 283 |
| Packing weight, g 50 mm x 50 mm cylinder | - | 141 | 143 | 150 | 145 | 146 | 146 |

* weight % of material added to sand
**average of three determinations

TABLE 14. Effect of scrubbing and washing on iron oxide and alumina analyses

| Sample | Before scrubbing | | After scrubbing | |
|---|---|---|---|---|
| | % $Fe_2O_3$ | % $Al_2O_3$ | % $Fe_2O_3$ | % $Al_2O_3$ |
| A | 0.18 | 0.20 | 0.22 | 0.13 |
| B | 0.19* | 0.18* | 0.19 | 0.18 |
| C | 0.66 | 6.47 | 0.28 | 0.55 |
| D | 0.30 | 2.77 | 0.35 | 2.79 |
| E | 0.39 | 1.01 | 0.08 | 0.20 |
| F | 0.16 | 0.41 | 0.17 | 0.11 |
| G | 0.06 | 0.67 | 0.05 | 0.35 |
| H | 0.09 | 0.78 | 0.07 | 0.41 |
| I | 2.77 | 13.10 | 3.03 | 13.20 |

*Estimated

TABLE 15. Comparison of all flotation versus combined magnetic separation and flotation

| Sample | Flotation only Analysis % | | | | Magnetic separation and flotation Analysis % | | | |
|---|---|---|---|---|---|---|---|---|
| | Test No. | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | Test No. | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ |
| A | 38 | 99.48 | 0.04 | 0.06 | 42 | 99.40 | 0.04 | 0.08 |
| B | 45 | 98.90 | 0.06 | 0.06 | 49 | 99.00* | 0.03 | 0.07 |
| C | 16 | 99.46 | 0.08 | 0.13 | 19 | 99.53 | 0.03 | 0.07 |
| D | 10 | 94.10 | 0.23 | 3.00 | 23 | 93.00* | 0.08 | 2.24 |
| E | 24 | 99.48 | 0.05 | 0.04 | 26 | 99.46 | 0.05 | 0.11 |
| F | 36 | 98.80* | 0.09 | 0.05 | 29 | 98.82 | 0.05 | 0.09 |
| G | 57 | 99.00* | 0.03 | 0.16 | 61 | 99.20* | 0.03 | 0.08 |
| H | 66 | 99.20* | 0.04 | 0.14 | - | - | - | - |
| I | 50 | 73.30 | 3.03 | 12.50 | 52 | 79.00 | 0.17 | 11.60 |

*Estimated

TABLE 16. Wet versus dry magnetic separation

| Sample | Wet separation % $Fe_2O_3$ | Dry separation % $Fe_2O_3$ |
|---|---|---|
| A | 0.04 | 0.04 |
| B | 0.04 | 0.04 |
| C | 0.06 | 0.05 |
| D | 0.08 | 0.09 |
| E | 0.06 | 0.04 |
| F | 0.06 | 0.07 |
| G | 0.05 | 0.04 |
| H | 0.06 | 0.05 |
| I | 0.14 | 0.18 |

# APPENDIX A

# APPENDIX A

## Nova Scotia Silica Study (Fenco Shawinigan Engineering)

### Introduction

Under contract to CANMET and under the auspices of the Canada/Nova Scotia Mineral Development Agreement, Fenco Shawinigan Engineering undertook a study of silica in Nova Scotia from the standpoint of resources and current and potential producers. The report of this study, dated September, 1985, examined, in particular, silica occurrences at five locations as follows: Brazil Lake, Belmont, Chegoggin Point, Diogenes Brook, and Elmsdale. Four of these are of interest as potential resources of sand for various applications including glass and silicon carbide manufacture, in foundry moulding application, and as sand-blast sand. The fifth, that at Chegoggin Point, is a tough, compact quartzite suitable for lump applications, e.g., as flux and in ferrosilicon manufacture, but not of particular interest for sand applications. The noted four sand occurrences, history of development, and present utilization or interest are briefly summarized below.

### Brazil Lake

Deposit : Brazil Lake (Nine Mile River)

Ownership : Nova Scotia Sand and Gravel

Location : 4 km north of Nine Mile River, Hants Co.

Description: Overburden varies from 2 to 10 m or more in depth, silica beds from 12 to 23 m in thickness; quartz represents 98% of observed minerals; kaolinitic clay, mica, feldspar, and heavy minerals are present in small amounts; quartz occurs as single as well as compound grains; grains sub-rounded to angular; reserves of high purity silica estimated at 750,000 tonnes.

Development: First commercial development 1979; operation continuing at present; sand washed, fines removed, and cleaned sand sold as sand-blast sand, foundry sand, and for miscellaneous uses; production averages 30,000 tonnes per year.

## Belmont

Deposit : Belmont (several deposits)
Ownership : Nova Scotia Sand and Gravel and Maritime Cement
Location : 10 km northwest of Truro, Colchester Co.
Description: Near surface deposits; well rounded, clear to frosted grains to sub-angular grains in finer sizes; reportedly high in iron and titanium minerals; of possible interest as foundry sand. Reserves at N.S.S.G pit reported to be 50,000 tonnes.
Development: Deposit(s) worked intermittently over the past 50 years, periodic production of sand as additive in portland cement manufacture.

## Diogenes Brook

Deposit : Diogenes Brook
Ownership : Unknown
Location : 3 km northwest of the village of Melford, Inverness Co., Cape Breton
Description: Bedded, with beds ranging up to 2 m in thickness; associated with coloured clay and lightly covered by glacial drift.
Development: Operated in early 1900's for foundry sand and stoneware clay; fine-grained, white to clear quartz, angular to sub-rounded; silica content 93 to 98%, accessory minerals include iron, alumina, muscovite, biotite, feldspar, tourmaline, rutile, magnetite, etc.; recent drilling places reserves at 7 million tonnes; work by Mines Branch, Ottawa, in 1930's indicated possibility of producing glass-grade sand from coarser sand, as well as suitability for sand-blast and foundry applications; clay has potential as pottery clay.

## Elmsvale

Deposit : Elmsvale
Ownership : Nova Scotia Sand and Gravel
Location : 1 to 2 km south of the town of Elmsvale, Halifax Co.
Description: Quartz associated with clay, silt, lignite and pyrite in formations that varies from 7 to 22 m in thickness; quartz grains angular to sub-rounded, silica content 95 to 98%; associated impurities include iron, alumina, clay and heavy minerals; reserves reported to be 3.5 million tonnes; test work carried out by Nova Scotia Technical College indicated non-suitability as resource of glass-grade sand
Development: No development at present

## Nova Scotia Silica Study (CANMET)

As part of a Federal/Provincial Mineral Development Agreement contract for a review of silica developments in Nova Scotia, Fenco Shawinigan Engineering Ltd., Halifax, provided sand samples from six deposits for laboratory study by CANMET. These samples were included in our 3-year project of the evaluation of silica resources in Canada.

These samples were received following completion of Phase III of the noted silica study - Silica Resources in Nova Scotia, New Brunswick, Manitoba, Saskachewan and British Columbia, and are therefore included as an Appendix rather than as part of the main report.

## Sample Identification and Description

The six samples received during the last quarter of 1985, were identified by letters A-A to A-F. The location of each is noted on the map, Fig. 1, and the samples are described in Table A1.

Each sample was examined under the binocular microscope; a brief physical description is presented in Table A2.

## Processing and Beneficiation

The four A-A samples, being similar in composition, were combined before further processing as were samples A-C-2 and A-C-3; A-E-1 and A-E-2. All contained coarse +2.4 mm and +1.7 mm material. This was removed by

screening and the finer, sand products were processed in the muller mixer to reduce agglomerates to grain size. This was followed by attrition scrubbing and washing and, finally, by high intensity dry magnetic separation to remove iron minerals. The coarse, +1.7 mm portion of sample A-A which represented about 28% of the total, was similarly processed by muller mixing, attrition scrubbing and magnetic separation.

Sample A-F, being obviously of very low grade, was not further treated.

## Results

Sieve analyses of all samples, as received, are shown in Table A3. Product recoveries with chemical analyses of the processed samples are reported in Table A4.

Samples of the -2.4 mm or -1.7 mm material that had been processed by scrubbing, washing, drying and magnetic separation were examined by binocular microscope. Results are summarized in Table A5.

## Discussion

Although these samples were 'grab' samples and not therefore truly representative of deposits, these results provide an indication of the degree of processing required to upgrade these sands.

Sizing followed by attrition scrubbing, washing, and magnetic separation produced a significant upgrading for most samples; however, end products, in all cases, contained excessive quantities of iron oxide and alumina impurities, in particular. These impurities, for glass-grade sand, should be less than 0.03 and 0.15% respectively.

The best results from the standpoint of glass-grade sand may be summarized as follows:

| Sample Identification | Recovery, Wt %* | Analysis, Wt % | | |
|---|---|---|---|---|
| | | $SiO_2$** | $Fe_2O_3$ | $Al_2O_3$ |
| A-A (-1.7 mm) | 60.7 | 99.1 | 0.09 | 0.23 |
| A-B (-2.4 mm) | 91.7 | 99.2 | 0.09 | 0.23 |
| A-E-3 (-1.7 mm) | 77.5 | 99.0 | 0.08 | 0.21 |

* Non-magnetic fraction
**By difference

The product resulting from the +1.7 mm portion of the combined A-A samples was low grade ($SiO_2$ 97.7%, $Fe_2O_3$ 0.18%, $Al_2O_3$ 0.83%; see Table A4).

Most of the samples contained significant quantities of +600 µm quartz (Table A3). This fraction is too coarse for glass manufacture. Removal of the +600 µm fraction followed by separate processing of the coarse and fine fractions is recommended, the -600 µm fraction being aimed at the glass manufacture market and the +600 µm fraction at silicon carbide and metallurgical flux markets.

Furthermore intensive processing of sized fractions, particularly of material represented by samples A-A, A-B and A-E-3, undoubtedly would result in much improved products.

TABLE A1. Sample identification and location

| Sample No. | Identification | Location |
|---|---|---|
| 85/14 | A-A-1 | Nine Mile River (Brazil Lake) |
| | A-A-2 | Nine Mile River (Brazil Lake) |
| | A-A-3 | Nine Mile River (Brazil Lake) |
| | A-A-4 | Nine Mile River (Brazil Lake) |
| 85/14 | A-B | Musquodoboit |
| 85/14 | A-C-1 | Belmont |
| | A-C-2 | Belmont |
| | A-C-3 | Belmont |
| 85-14 | A-D | Indian Head |
| 85-14 | A-E-1 | Diogenes Brook |
| | A-E-2 | Diogenes Brook |
| | A-E-3 | Diogenes Brook |
| 85-25 | A-F | Elmsdale |

TABLE A2. Sample description

| Sample | Description |
|---|---|
| A-A-1 to A-A-4 | All four samples were generally similar; samples were creamy white in colour and contained some lumps of clay-bonded quartz sand ranging up to 35 mm in size; lumps mostly could be reduced to sand-size by hand crushing; the sand-sized material essentially consisted of sub-rounded to sub-angular, clay-coated grains of quartz with minor grey to black mineral impurities; these impurities tended to concentrate in the finer sizes. |
| A-B | This sample essentially consisted of sub-rounded to sub-angular grains of dark coloured, spotted quartz with minor feldspar and metallic-like impurities. |
| A-C-1 to A-C-3 | All three samples were reddish brown in colour and generally similar; quartz grains were rounded to sub-rounded and iron-stained; many compound grains with attached dark mineral impurities were present; minor mica observed. |
| A-D | Essentially composed of clay-bonded, sub-rounded quartz grains with lumps up to 25 mm in size; quartz relatively fine, -300 µm; minor dark mineral impurity in the fine fractions. |
| A-E-1 to A-E-3 | Sample A-E-1 and A-E-2 were generally similar with some vegetable matter and a substantial quantity of impurities in the coarser, +2 mm sizes; the quartz grains were sub-rounded and clay-coated; minor mica was present together with dark mineral impurities, especially in the finer sizes.<br><br>Sample A-E-3 was of higher purity than either A-E-1 or A-E-2; grains were sub-rounded, clay-coated and essentially free at 1 mm size. |
| A-F | This sample was very low grade and essentially consisted of dark brown, clay-coated impure sand with lumps up to 30 mm in size. |

TABLE A3. Sieve analyses

| Size (μm) | Direct % weight | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A-A-1 | A-A-2 | A-A-3 | A-A-4 | A-B | A-C-1 | A-C-2 | A-C-3 | A-D | A-E-1 | A-E-2 | A-E-3 |
| +1700 | 28.1 | 28.1 | 28.1 | 28.1 | 1.4 | 4.9 | 4.1 | 4.1 | - | 14.8 | 14.8 | 8.9 |
| -1700+ 840 | 12.2 | 13.6 | 15.2 | 12.2 | 47.2 | 4.3 | 1.6 | 1.6 | 17.7 | 3.4 | 0.9 | 2.6 |
| - 840+ 590 | 10.7 | 10.4 | 11.4 | 10.6 | 24.3 | 10.7 | 6.4 | 5.9 | 17.8 | 4.3 | 1.8 | 18.9 |
| - 590+ 420 | 9.9 | 8.8 | 9.9 | 9.9 | 10.9 | 17.5 | 13.0 | 11.8 | 21.3 | 5.0 | 4.7 | 37.4 |
| - 420+ 300 | 12.2 | 10.3 | 11.4 | 12.2 | 7.1 | 22.4 | 19.1 | 17.9 | 18.4 | 11.8 | 15.7 | 19.6 |
| - 300+ 210 | 9.9 | 9.2 | 8.9 | 9.5 | 3.7 | 16.2 | 19.9 | 20.3 | 9.0 | 23.6 | 18.5 | 6.6 |
| - 210+ 150 | 7.5 | 9.1 | 7.0 | 7.5 | 2.5 | 10.4 | 16.6 | 16.9 | 7.6 | 18.1 | 19.2 | 3.3 |
| - 150+ 105 | 3.8 | 4.4 | 3.4 | 4.0 | 1.5 | 6.0 | 9.9 | 10.8 | 3.1 | 6.9 | 11.8 | 1.3 |
| - 105 | 5.7 | 6.1 | 4.7 | 6.0 | 1.4 | 7.6 | 9.4 | 10.7 | 5.1 | 12.1 | 12.6 | 1.4 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

TABLE A4. Product analyses and selected distributions

| Products | Wt % | Analyses | | | | | | | | | | Distribution | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $TiO_2$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | Total | $SiO_2$ | $Fe_2O_3$ | $Al_2$ |
| Sample A-A† (-1.7 mm) | | | | | | | | | | | | | | |
| Head sample | 100.0 | 95.78 | 0.30 | 1.88 | 0.27 | n.d. | n.d. | 0.10 | 0.04 | n.d. | - | 100.0 | 100.0 | 100. |
| Dry screening | | | | | | | | | | | | | | |
| +1.7 mm | 28.1 | 94.96 | 0.35 | 2.50 | 0.23 | n.d. | n.d. | 0.10 | 0.10 | n.d. | - | 27.9 | 32.8 | 37. |
| -1.7 mm | 71.9 | 96.1 | 0.28 | 1.63 | 0.28 | 0.02 | 0.06 | <0.10 | 0.02 | 0.83 | 99.32 | 72.1 | 67.2 | 62. |
| Attrition scrubbing | | | | | | | | | | | | | | |
| -1.7 mm + 100 µm | 65.1 | 98.4 | 0.17 | 0.32 | 0.25 | 0.02 | 0.02 | <0.10 | 0.01 | 0.29 | 99.58 | 48.2 | 24.8 | 6. |
| -100 µm | 6.8 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dry magnetic separation | | | | | | | | | | | | | | |
| magnetics | 3.7 | - | 10.5 | 3.82 | 23.2 | - | - | - | - | - | - | - | - | - |
| middlings | 0.7 | - | 0.24 | 0.58 | 0.48 | - | - | - | - | - | - | - | - | - |
| non-magnetics | 60.7 | 99.1* | 0.09 | 0.23 | 0.06 | 0.02 | 0.01 | <0.1 | 0.01 | 0.32 | 99.94 | 45.3 | 12.2 | 4. |

n.d. - not determined
* By difference
†Combined samples

TABLE A4. Product analyses and selected distributions

| Products | Wt % | Analyses | | | | | | | | | | Distribution | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $TiO_2$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | Total | $SiO_2$ | $Fe_2O_3$ | $Al_2$ |
| Sample A-A (+1.7 mm) | | | | | | | | | | | | | | |
| Head sample | 28.1 | 94.96 | 0.35 | 2.50 | 0.23 | n.d. | n.d. | 0.10 | 0.10 | n.d. | - | 27.9 | 32.8 | 37 |
| Dry screening | | | | | | | | | | | | | | |
| +4.8 mm | 5.8 | - | - | - | - | - | - | - | - | - | - | - | - | |
| -4.8mm + 1.7 mm | 22.3 | 96.3* | 0.29 | 1.55 | 0.15 | 0.02 | 0.09 | <0.1 | 0.03 | 0.79 | 99.32 | 22.5 | 21.6 | 18 |
| Attrition scrubbing | | | | | | | | | | | | | | |
| -4.8 mm + 1.7 mm | 20.3 | 97.0* | 0.19 | 1.30 | 0.12 | 0.02 | 0.07 | <0.1 | 0.03 | 0.59 | 99.42 | 20.6 | 12.9 | 14 |
| -100 µm | 2.0 | - | - | - | - | - | - | - | - | - | - | - | - | |
| Dry magnetic separation | | | | | | | | | | | | | | |
| magnetics | 1.6 | - | 1.49 | 4.32 | 0.98 | - | - | - | - | - | - | - | - | |
| middlings | 0.8 | - | 0.56 | 2.95 | 0.54 | - | - | - | - | - | - | - | - | |
| non-magnetics | 17.9 | 97.7* | 0.18 | 0.83 | 0.11 | 0.03 | 0.05 | <0.10 | 0.04 | 0.58 | 99.62 | 18.3 | 10.8 | 7 |

n.d. - not determined
*By difference

TABLE A4. Product analyses and selected distributions

| Products | Wt % | Analyses | | | | | | | | | | Distribution | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $TiO_2$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | Total | $SiO_2$ | $Fe_2O_3$ | $Al_2O$ |
| Sample A-B | | | | | | | | | | | | | | |
| Head sample | 100.0 | 97.3 | 0.29 | 0.35 | 0.04 | n.d. | n.d. | 0.05 | 0.01 | n.d. | - | 100.0 | 100.0 | 100.( |
| Dry screening | | | | | | | | | | | | | | |
| +2.4 mm | 1.4 | 97.2 | 0.22 | 0.41 | 0.04 | n.d. | n.d. | 0.05 | 0.03 | n.d. | - | - | - | - |
| -2.4 mm | 98.6 | 97.3* | 0.29 | 0.35 | 0.04 | 0.02 | 0.03 | <0.1 | <0.01 | 1.43 | 99.57 | 98.6 | 98.6 | 98.( |
| Attrition scrubbing | | | | | | | | | | | | | | |
| -2.4 mm + 100 µm | 93.9 | 99.1 | 0.15 | 0.19 | 0.04 | 0.01 | 0.02 | <0.1 | <0.01 | 0.29 | 99.91 | 95.6 | 48.6 | 51.( |
| -100 µm | 4.7 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dry magnetic separation | | | | | | | | | | | | | | |
| magnetics | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| middlings | 2.2 | - | 1.04 | 0.46 | 0.19 | - | - | - | - | - | - | - | - | - |
| non-magnetics | 91.7 | 99.2* | 0.09 | 0.23 | 0.02 | 0.01 | 0.01 | <0.1 | 0.01 | 0.30 | 99.97 | 93.5 | 28.5 | 60. |

n.d. = not determined
*By difference

TABLE A4. Product analyses and selected distributions

| Products | Wt % | Analyses | | | | | | | | | | Distribution | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $TiO_2$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | Total | $SiO_2$ | $Fe_2O_3$ | $Al_2($ |
| Sample A-Cn1 | | | | | | | | | | | | | | |
| Head sample | 100.0 | 93.8 | 0.60 | 2.82 | 0.70 | n.d. | n.d. | 0.09 | 0.02 | n.d. | - | 100.0 | 100.0 | 100. |
| Dry screening | | | | | | | | | | | | | | |
| +1.7 mm | 4.9 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| -1.7 mm | 95.1 | 94.2 | 0.60 | 2.76 | 0.70 | 0.04 | 0.33 | <0.1 | 0.02 | 1.15 | 99.90 | 95.5 | 95.1 | 93. |
| Attrition scrubbing | | | | | | | | | | | | | | |
| -1.7 mm + 100 µm | 81.5 | 97.3 | 0.32 | 0.53 | 0.55 | 0.02 | 0.11 | <0.1 | 0.02 | 0.36 | 99.31 | 84.5 | 43.5 | 15. |
| -100 µm | 13.6 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dry magnetic separation | | | | | | | | | | | | | | |
| magnetics | 1.3 | - | 16.1 | 2.82 | 26.5 | - | - | - | - | - | - | - | - | - |
| middlings | 0.9 | - | 0.77 | 2.06 | 2.76 | - | - | - | - | - | - | - | - | - |
| non-magnetics | 79.3 | 98.6* | 0.10 | 0.49 | 0.22 | 0.02 | 0.09 | <0.1 | 0.01 | 0.34 | 99.97 | 83.4 | 13.2 | 13. |

n.d. - not determined
*By difference

TABLE A4. Product analyses and selected distributions

| Products | Wt % | Analyses | | | | | | | | | | Distribution | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $TiO_2$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | Total | $SiO_2$ | $Fe_2O_3$ | $Al_2O$ |
| Sample A-C-2&3 | | | | | | | | | | | | | | |
| Head sample | 100.0 | 95.0 | 0.60 | 1.80 | 0.30 | n.d. | n.d. | 0.12 | 0.03 | n.d. | - | 100.0 | 100.0 | 100. |
| Dry screening | | | | | | | | | | | | | | |
| +1.7 mm | 4.1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| -1.7 mm | 95.9 | 95.3* | 0.51 | 1.63 | 0.28 | 0.11 | 0.80 | <0.1 | 0.02 | 0.66 | 99.41 | 96.2 | 81.5 | 86. |
| Attrition scrubbing | | | | | | | | | | | | | | |
| -1.7 mm + 100 µm | 89.7 | 96.3 | 0.42 | 1.39 | 0.37 | 0.10 | 0.75 | <0.1 | 0.02 | 0.29 | 99.74 | 90.9 | 62.8 | 69. |
| -100 µm | 6.2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dry magnetic separation | | | | | | | | | | | | | | |
| magnetics | 1.3 | - | 12.4 | 4.36 | 14.2 | - | - | - | - | - | - | - | - | - |
| middlings | 6.1 | - | 0.92 | 2.59 | 1.63 | - | - | - | - | - | - | - | - | - |
| non-magnetics | 82.3 | 97.3* | 0.30 | 1.09 | 0.11 | 0.07 | 0.65 | <0.1 | 0.01 | 0.31 | 99.94 | 84.3 | 41.2 | 49. |

n.d. - not determined
*By difference

TABLE A4. Product analyses and selected distributions

| Products | Wt % | Analyses | | | | | | | | | | Distribution | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $TiO_2$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | Total | $SiO_2$ | $Fe_2O_3$ | $Al_2($ |
| Sample A-D | | | | | | | | | | | | | | |
| Head sample | 100.0 | 89.7 | 0.42 | 6.14 | 0.33 | 0.08 | 0.62 | <0.1 | 0.03 | 2.22 | 99.64 | 100.0 | 100.0 | 100. |
| Dry screening | | | | | | | | | | | | | | |
| +1.7 mm | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| -1.7 mm | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Attrition scrubbing | | | | | | | | | | | | | | |
| -1.7 mm + 100 µm | 71.0 | 96.8 | 0.18 | 0.96 | 0.33 | 0.03 | 0.14 | <0.1 | 0.01 | 0.40 | 98.95 | 76.6 | 30.4 | 11 |
| #100 µm | 29.0 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dry magnetic separation | | | | | | | | | | | | | | |
| magnetics | 0.6 | - | 8.76 | 4.62 | 19.8 | - | - | - | - | - | - | - | - | - |
| middlings | 7.0 | - | 0.26 | 1.71 | 1.10 | - | - | - | - | - | - | - | - | - |
| non-magnetics | 63.4 | 98.3* | 0.10 | 0.79 | 0.19 | 0.02 | 0.09 | <0.1 | 0.02 | 0.34 | 99.95 | 69.5 | 15.1 | 8 |

n.d. - not determined
*By difference

TABLE A4. Product analyses and selected distributions

| Products | Wt % | Analyses | | | | | | | | | | Distribution | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $TiO_2$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | Total | $SiO_2$ | $Fe_2O_3$ | $Al_2$ |
| Sample A-E-1&2 | | | | | | | | | | | | | | |
| Head sample | 100.0 | 94.2 | 0.51 | 2.95 | 0.25 | n.d. | n.d. | 0.13 | 0.08 | n.d. | - | 100.0 | 100.0 | 100 |
| Dry screening | | | | | | | | | | | | | | |
| +1.7 mm | 14.8 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| -1.7 mm | 85.2 | 95.0 | 0.36 | 2.50 | 0.23 | 0.07 | 0.43 | <0.1 | 0.06 | 1.21 | 99.96 | 85.9 | 60.1 | 72 |
| Attrition scrubbing | | | | | | | | | | | | | | |
| -1.7 mm + 100 µm | 76.7 | 97.9 | 0.19 | 0.69 | 0.14 | 0.05 | 0.12 | <0.1 | 0.04 | 0.32 | 99.55 | 79.7 | 28.6 | 17 |
| -100 µm | 8.5 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dry magnetic separation | | | | | | | | | | | | | | |
| magnetics | 0.7 | - | 7.54 | 10.3 | 6.33 | - | - | - | - | - | - | - | - | - |
| middlings | 7.6 | - | 0.34 | 1.36 | 0.31 | - | - | - | - | - | - | - | - | - |
| non-magnetics | 68.4 | 98.5* | 0.19 | 0.46 | 0.07 | 0.03 | 0.05 | <0.1 | 0.01 | 0.34 | 99.75 | 71.5 | 25.5 | 10 |

n.d. - not determined
*By difference

TABLE A4. Product analyses and selected distributions

| Products | Wt % | Analyses | | | | | | | | | | Distribution | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $TiO_2$ | $Na_2O$ | $K_2O$ | MgO | CaO | LOI | Total | $SiO_2$ | $Fe_2O_3$ | $Al_2$ |
| Sample A-E-3 | | | | | | | | | | | | | | |
| Head sample | 100.0 | 95.7 | 0.28 | 2.48 | 0.13 | n.d. | n.d. | 0.05 | 0.03 | n.d. | - | 100.0 | 100.0 | 100. |
| Dry screening | | | | | | | | | | | | | | |
| +1.7 mm | 8.9 | - | - | - | - | - | - | - | - | - | - | - | - | |
| -1.7 mm | 91.1 | 95.9* | 0.27 | 2.32 | 0.12 | 0.01 | 0.09 | <0.1 | 0.03 | 1.13 | 99.97 | 91.3 | 87.9 | 85. |
| Attrition scrubbing | | | | | | | | | | | | | | |
| -1.7 mm + 100 µm | 79.9 | 98.7* | 0.09 | 0.27 | 0.06 | 0.01 | 0.02 | <0.1 | 0.01 | 0.22 | 99.48 | 82.4 | 25.7 | 8. |
| -100 µm | 11.2 | - | - | - | - | - | - | - | - | - | - | - | - | |
| Dry magnetic separation | | | | | | | | | | | | | | |
| magnetics | 0.3 | - | 10.9 | 16.9 | 10.9 | - | - | - | - | - | - | - | - | |
| middlings | 2.1 | - | 0.35 | 0.92 | 0.55 | - | - | - | - | - | - | - | - | |
| non-magnetics | 77.5 | 99.0* | 0.08 | 0.21 | 0.05 | 0.01 | 0.02 | <0.1 | 0.01 | 0.30 | 99.78 | 80.2 | 22.1 | 6. |

n.d. - not determined
*By difference

TABLE A5. Processed sample description

| Sample (Non-magnetic fraction) | Description |
|---|---|
| A-A (-1.7 mm, combined samples) | Product creamy white in colour, essentially composed of sub-rounded to sub-angular quartz; some clay-coating on grains; minor staining, minor dark impurities. |
| A-B (-2.4 mm) | Product grey in colour, essentially composed of sub-rounded to sub-angular quartz; minor clay/kaolin in pockets in quartz grains, some dark quartz and mineral impurity. |
| A-C-1 (-1.7 mm) | Product light reddish-brown colour, essentially composed of rounded to sub-rounded quartz grains; most grains coated with red iron-oxide; minor dark impurities. |
| A-C-2&3 (-1.7 mm) | Product was darker in colour than A-C-1; rounded to sub-rounded quartz; minor impurities including a few grains of feldspar. |
| A-D (-1.7 mm) | Light brown in colour; rounded to sub-rounded grains of quartz; minor kaolin-coating and bonding, iron staining and dark impurities. |
| A-E-1&2 (-1.7 mm) | Creamy white in colour, sub-rounded to sub-angular grains of quartz; minor impurities including feldspar. |
| A-E-3 (-1.7 mm) | Generally purer than A-E-1&2 samples, otherwise similar. |